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SUMMARY

Preliminary studies done under DSS contract No. 03SQ.23440-2-9009 on the Chemical Comminution of Asbestos had indicated that significant energy savings may be achieved using wet comminution techniques instead of the traditional dry milling operation. However, several major problems were encountered when processing ore by these new techniques. This study addresses some of these problems.

The first area studied was the use of surfactants and their effect on dry milled asbestos fibre selected by the scientific authority. Previous work examined the effect of a number of chemical surfactants (Aerosol OT, Sodium Oleate, Sodium Laurate) on the opening characteristics of asbestos fibre. This effect was further studied under this contract using Aerosol OT. Opening characteristics were quantified using the Turner and Newall Elutriator.

The investigation indicated that the removal of surfactant after opening presented a problem. Various removal procedures including aqueous dilution, alkali, and solvent washings were investigated.

It was found that, although chemical treatment of asbestos does show some indication of a gentle opening of fibre bundles, problems associated with surfactant removal supersedes any possible benefits.

The second task was to develop a viable wet extraction circuit capable of processing asbestos tailings material. Tailings material was chosen for this study because the size reduction, and therefore energy, required to liberate the fibre that had already been put into the material during dry processing of the asbestos ore. This eliminated the need for crushing or grinding equipment. Studies concentrated on fibre recovery through classification, and crudy fibre opening with operations such as the attrition mill.

Fibre concentrate produced by the wet extraction circuit developed in this study was then compared to fibre concentrates produced by a standard dry core mill circuit. Several conclusions may be reached. The final form of the wet extraction circuit developed had two elutriation cones providing primary and secondary rock and grit removal. A high speed attrition mill placed in between the two cones provided some opening to the crude fibre that overflowed the first elutriation cone. The second cone overflow was passed through the rotating trommel screen where it was dewatered and washed by inner and outer sprays. The partially dewatered and dedusted material fed onto the concentrating table, where it was classified, giving a fibre concentrate, a middlings product and a tailings. Fibre products were dewatered and further dedusted on a Sweco screen equipped with a rotary spray.

The quality of the fibre products from the individual test runs of each tailings sample were tested, using the Bauer-McNett Classifier, the Turner and Newall Rapid Surface Area, and the Fibre Strength Unit. The fibre recovered using the wet extraction circuit was consistently less dusty (i.e. less -200 mesh by Bauer-McNett) than that produced by the dry circuit. The wet circuit also produced fibre with a higher strength unit value.

The wet circuit did not require any chemical surfactants to produce cleaner, stronger fibre. Wet circuit provided a gentle means of fibre opening, and dust removal that resulted in a stronger product, as measured by the Fibre Strength Unit.

When mathematically blended and dust adjusted to an arbitrary dust level, fibre recovered from the wet circuit showed no consistent difference than fibre recovered from the dry circuit, for a given tailings sample. This suggests that the wet extraction circuit is, at least, as efficient in recovering fibre as the dry.

The energy survey conducted on the wet and dry processes indicated that the wet process required less energy to produce a given amount of fibre than did the dry process. This study indicated an energy savings of approximately 30%. This study did not include the cost of water supply for the wet process, or the energy cost for the aspiration and

environmental control needed for the dry circuit. It is recommended that an energy comparison be made with commercial dry circuits. This would give a much more significant measure of the relative practicality of the wet process.

1. INTRODUCTION

The previous contract concluded that fibre-gangue separation needed to be optimized. Initial testing was done on Alaskan fibre tailing material, originally processed through a dry mill. This material was all passing 35 mesh and was therefore easily within the capacity of the hydrocyclone circuit designed to separate fibre from gangue. Fibre-gangue separation was achieved at this particle size feed material.

A second series of tests were conducted on a sample of Canadian ore. It was found that this feed material contained rock fragments large enough to plug the hydrocyclone. A rock reduction circuit would have produced a proper feed material, but the rock fragments that plugged the hydrocyclone were already smaller than the typical "run-of-mill" material. By modifying the operating pressures, the vortex finder and the spigot enabled the hydrocyclone to process this grit, but considerable quantities of fibre were rejected in the underflow. Clearly, a coarse grit separation at the front end of the circuit was required.

A coarse degritting system was developed, with three agitation/decantation stages replacing the hydrocyclone. The run-of-mill ore was agitated in the first vessel so that the fibre and smaller grit remained in suspension, while the coarse material sank. This suspension was pumped into the next vessel where this process was repeated. Three stages produced a fibre relatively grit free. Examination of the rejected material that settled to the bottom of each vessel indicated that a significant amount of fibre was rejected. This was confirmed by drying and screening the reject. Optimization of the degritting system was required.

A second processing problem, not significant in small scale batch testing, but very significant in continuous production is that of dewatering. Fibre produced by the various wet processing circuits in these initial studies was collected as dilute slurries. The slurry was allowed to settle; the clean water was decanted, and the concentrate was pressure filtered to give a product. The various sieve bends used were not fine enough, allowing much of the fibre to pass through. Although the sieve bend may be used as a classifier, a dewatering system was still required.

A third problem encountered by these initial studies was the effect of the chemical surfactants on the fibre produced. The surfactants lowered energy consumption during processing and increased recovery. The fibre, however, had absorbed the surfactant, which caused problems in the characterization tests. Proper surface areas would not be taken since the surfactant tended to matt and bind the fibre together. Wet length classification tests were inconclusive since the fibre was often hydrophobic. Sample dispersion and foaming in the wet characterization tests were common with the treated fibre. Removal of the surfactants was necessary before testing could be done.

Two techniques of surfactant removal were addressed: heat treatment and washing. Heat treatment of the fibre at 350°C removed the surfactant and did not appear to degrade the crystal structure of the fibre. The heat treated fibre could be characterized by the conventional tests. Although successful, this method of surfactant removal was energy-intensive. Any energy savings occurred in the wet process would be lost in heat treatment. Washing or diluting the fibre was partially successful in removing the surfactant. This suggested that further work may offer some solution along these lines.

The following report describes the program undertaken to address the problems encountered in the previous study. Wet mill designs were tested in comparison to a standard dry mill for three Canadian asbestos tailing samples. Energy consumption, capacities and product quality were compared.

The program involved separate sub-tasks. The first looked at the effect of surfactants on the fibre, and attempted various means of removing these surfactants. The second task developed a wet circuit to concentrate fibre from dry processed tailings material. Much of this study involved flow sheet development, and as such, has been reported in a chronological order.

2. SURFACTANT STUDIES

Work conducted under Phase I of the "Energy Conservation by Chemical Comminution of Asbestos" program (UP-0-169 DSS Contract No. 035Q23440-3-9009) examined the effects of various contacting techniques (ball milling and stirring) with a number of chemical surfactants (Aerosol OT, Sodium Oleate, Sodium Laurate) that had been identified as active chemicals for inducing

Canadian asbestos fibre opening. The fibre generated in this program, however, showed distinct evidence of having adsorbed surfactant on its surfaces which produced a hydrophobic material. This adsorption proved to be detrimental in the traditional characterization of the fibre produced in pilot scale wet/chemical processes and, although a number of removal techniques were attempted (i.e. heat treating, solvent and alkali washing), these met with limited success, partially due to inability to quantify the degree of surfactant adsorption/removal.

The current study involves the measurement of the degree of chemical adsorption and removal by quantifying the amount of surfactant present in solution. For the purposes of this study, Aerosol OT was selected as the chemical surfactant owing to its extreme activity in dispersing asbestos fibre of Canadian chrysotile. The first stage of this laboratory work was to develop a methodology for measuring the aqueous concentration of Aerosol OT. Once a standard test had been developed, the degree of surfactant removal was examined by a variety of procedures, including simple aqueous dilution, alkali, and solvent washings. The final stage examined the degree of fibre opening obtained by conducting a series of Turner & Newall Elutriations which quantifies the percentage of crude, partly opened, opened and dust present in a fibre sample.

2.1 QUANTITATIVE ANALYSIS OF AEROSOL OT

Aerosol OT (also known as Vatsol-OT) is one of the most powerful wetting agents and surface tension depressants available. Its chemical form is a dioctyl ester of sodium sulfosuccinate and, as such, is known as an anionic surfactant, thereby interacting with the positively charged surface layer of chrysotile asbestos in the pH range 5.5 - 10. Aerosol OT is thought to assist in the opening of asbestos fibrils by attaching itself to these positive sites whereby the negatively charged "free" ends of the surfactant repel each other to separate the asbestos fibrils. If this is indeed the case, there would appear to be an optimum concentration of Aerosol OT needed to dissociate a given mass of asbestos fibre, however quantifying this amount may be difficult due to the retention (adsorption) of Aerosol OT on the fibre surface.

After consulting with the manufacturer of Aerosol OT (Canadian Cyanamid), a standard test for determining the concentration of surface-active agents in aqueous media was investigated. The test was based upon a procedure developed by Wallin ⁽¹⁾ and involves the colorimetric detection of a chloroform-soluble magenta-coloured extract which is formed from the reaction of basic fushsin (rosaniline/ pararosaniline) and dioctyl ester of sodium sulfosuccinic acid (the acid form of Aerosol OT at low pH). The entire experimental procedure is reported here for the sake of completeness.

A sample containing between 0.05 and 0.8 mg of active agent (aerosol OT) is placed in a 125 ml separatory funnel and diluted to approximately 20 ml with distilled water. A sufficient quantity of concentrated hydrochloric acid is added to reduce the pH to 1.2 as determined by a pH meter. Two millilitres of 0.1% aqueous basic fuchsin are then added and mixed and subsequently extracted with 20 ml of chloroform ACS grade). The extraction is repeated until clear (generally 3 times) while collected each fraction in a 100 ml volumetric flask after passing through a column (~3 cm ϕ) filled with 2 g of absorbant cotton. The cotton plug is then washed through with fresh chloroform, collected, and the 100 ml flask made up to the mark. A small portion of each flask is then analyzed using a photospectrometer which has been previously zeroed with chloroform. The spectrometer reading is then compared to a calibration curve prepared with accurately known amounts of Aerosol OT.

Preliminary evaluations examined the optimum absorbance wavelength using a 0.5 mg Aerosol OT sample. The absorbance results are depicted in Figure 1. The analysis wavelength was subsequently chosen at 555 nm. It was noted during the the first few tests that the quantity and/or quality of absorbant cotton employed greatly affected the observed results. The absorbant cotton

(1) Wallin, G. R., J. Anal. Chem., 22, #4, 616-17 (1950).

is used in these tests to remove the water-soluble dye following the aqueous/chloroform extraction. A number of commercially available absorbant cottons were investigated, and it was concluded that using approximately 2 g of Johnson & Johnson Red Chain absorbant cotton gave highly reproducible results. The spectrophotometer used was a Perkin-Elmer 35.

A calibration curve was prepared using Aerosol OT concentrations ranging from 0.04 - 0.8 mg (see Figure 2). The data may be represented as a linear plot between the limits of 0.1 - 0.9 absorbance by the following equation.

$$\text{mg Aerosol OT} = (\text{Absorbance} \times 0.7894) + 0.0152$$

The reproducibility expected between identical analyses is expected to be in the order of 1 - 2%.

2.2 ASSESSMENT OF SURFACTANT ADSORPTION AND REMOVAL

As described previously, a number of surfactant removal techniques have been employed for the Aerosol OT/asbestos fibre combination i.e. heat treating, alkali and/or solvent washing). Heat treatment, although effective from the removal aspect, suffers from the drawbacks of being highly energy-intensive (and therefore costly), as well as producing a fibre which may have structural deficiencies as a result of the dehydroxylation of asbestos at the heating temperatures ($\sim 350^{\circ}\text{C}$). To assess a more cost-effective treatment, three types of surfactant removal techniques were investigated under controlled conditions: simple aqueous dilution, alkali washing (with NaOH), and solvent washing (with methanol). Each technique was applied to a previously dry-milled Canadian chrysotile fibre blend which was selected by the scientific authority.

2.2.1 Aqueous Dilution

Simple aqueous dilution offers a number of advantages over using alternate chemical reagents. Avoiding the separation/environmental problems associated with organic solvents or caustic solutions is perhaps the most important feature. Aqueous dilution also avoids any problems due to chemical interaction of the fibre itself, thereby eliminating any

potential application difficulties (i.e. strength properties, filterability, etc.).

To assess the effectiveness of aqueous dilution, a number of chrysotile asbestos samples were contacted with varying concentrations of Aerosol OT. The samples were then filtered and redispersed in specific volumes of clean distilled water. The concentration of Aerosol OT was then measured to determine the degree of surfactant desorbed from the asbestos fibre mat. This procedure was repeated until the desorbed surfactant concentration remained constant. Table I and Figure 3 show the results of these tests.

From these results, it appears that there is an approximate 51% retention ($\pm 8\%$) of the original surfactant on the asbestos fibres for concentrations up to 0.2%. Above this limit, the excess surfactant tends to be removed with the wash water, thereby indicating a maximum retention capacity for the fibre in question of around 12%, based upon fibre weight. It is also evident that one requires at least a two-fold excess of this maximum to realize total adsorption.

From Figure 3, it is apparent that an approximate 1000-fold dilution is required to adequately remove all of the non-adsorbed surfactant.

2.2.2 Alkali Washing

The removal of adsorbed Aerosol OT by washing with caustic solutions (1M NaOH) was previously investigated and found to have met with limited success. Differential thermograms for the washed fibre showed a probable change in the chemical structure of the absorbed species. To confirm this, a set of standard Aerosol OT concentration solutions were mixed to a specific molarity of sodium hydroxide ranging from 0 - 0.5 M. The results of these tests are depicted in Figure 4, and show a near total conversion of active Aerosol OT component for high NaOH molarities (>1 M). This is a result of a hydrolysis reaction above pH = 10. This suggests that the Aerosol OT is not removed from the fibre but changes its chemical nature, the effect of which may still influence the fibres' physical characteristics.

2.2.3 Methanol Washing

Methanol has been shown to be relatively effective in removing Aerosol OT from treated asbestos fibres. Differential thermograms show that double washings appear to remove a large proportion of the adsorbed surfactant. To quantify more carefully the degree of surfactant removal, asbestos fibre (at 1% slurry concentration) was treated with Aerosol OT (at 0.05 and 0.5%), filtered and then diluted with methanol (at ~2.5% slurry concentration). A portion of this wash solution was analyzed through the procedure described in Section 1.2. Table II shows the results of this analysis.

Methanol was also used as a final wash on the 0.1% and 0.2% aqueous dilutions of Table I. Approximately 5.9 mg and 4.6 mg of Aerosol OT were removed, respectively, by using a 50 ml methanol wash as the final surfactant removal technique. This does not differ significantly from that removed via simple aqueous dilutions (4.5 mg and 2.1 mg, respectively). It is therefore suggested the aqueous washings are a more desired surfactant removal technique since the complications of using organic solvents are circumvented.

TABLE II

METHANOL WASHING OF CONTACTED ASBESTOS FIBRE

Asbestos Slurry Concern- tration	Aerosol OT Concern- tration	Aerosol OT Removed with Aqueous Solution (mg) (% of total)	Aerosol OT Removed with Methanol Wash (mg) (% of total)	Total Aerosol OT Removed (mg) (%)
1.0%	0.05%	27.6 22.0	32.2 25.7	59.8 47.7
1.0%	0.05%	253.0 20.2	319.6 25.6	572.6 45.8

2.3 ASSESSMENT OF CHEMICAL OPENING

To study the opening effects of chemical treatment in the wet processing of asbestos fibre, a series of Turner and Newall (T&N) Elutriation tests were conducted of fibre contacted with Aerosol OT. The T&N test assesses the degree of fibre opening obtained by determining the weight fractions in each of the following classifications: crude and feather, partly open, open, and -200M (dust).

As mentioned earlier, fibre contacted with Aerosol OT assumes a very hydrophobic nature, and it is therefore necessary to attempt some type of surfactant removal before conducting any elutriation tests. One thousand-fold aqueous dilution was chosen to avoid any complexities in dealing with non-aqueous or caustic solutions. The T&N tests were conducted on the following samples:

- (1) dry lifted fibre,
- (2) dry lifted fibre stirred in water for 1/2 hour at 1% solids,
- (3) dry lifted fibre stirred in 0.1% Aerosol OT solution for 1/2 hour @ 1% solids, then diluted 1000X and stirred for 1/2 hour,
- (4) as in (3) but 0.2% Aerosol OT,
- (5) as in (3) but 0.5% Aerosol OT,
- (6) dry lifted fibre stirred in 0.5% Aerosol OT solution for 1/2 hour @ 1% solids, then contacted with 1M NaOH for 1/2 hour.

Test (2) was conducted as a control and measured in triplicate to assess the reproducibility of the T&N technique as well as to assign error limits to the observed values. A one-hour aqueous stir study was also conducted, and the values measured did not vary significantly from those for the 1/2 hour tests. Table III gives the observed T&N results for the above conditions.

TABLE III

Test #	T&N Elutriator (%)			
	Crude + Feather	Partly Open	Open	-200
1	14.3	13.9	36.9	34.9
2	17.6 $\pm$ 2.8	8.7 $\pm$ 2.2	41.4 $\pm$ 2.6	32.3 $\pm$ 2.0
3	16.5	1.7	56.5	25.3
4	10.8	1.3	61.0	27.1
5	18.2	2.0	45.5	34.3
6	15.9	1.7	46.6	35.8

From the results of Table III, it appears that simple aqueous stirring has a tendency to slightly open fibres which report as partly open for the dry lifted sample. This effect does not appear to be excessively dramatic (typically 3 - 5% shift), therefore not a great deal is expected to be gained in opening by simple aqueous agitation.

Treatment of the asbestos fibre with Aerosol OT does, however, appear to produce a significant increase in the amount of opened fibre present. This is particularly evident for the lower Aerosol OT concentrations (i.e. 0.1% and 0.2%, tests 3 and 4, respectively), where the percentage of open fibre has increased by approximately 15% units. This dramatic increase appears to be a result of a decrease in both the partly opened and -200 fractions, which suggests that not only is the fibre being opened chemically, but smaller fibrils are being bound together to form longer "fibres".

To ensure that this increase in opened fibre is not a result of hydrophobic fibre being "floated" into the open fibre tank (as was observed in the previous study), one test was conducted on the fibre contacted with 0.5% Aerosol OT after it had been treated with 1M NaOH to "modify" the adsorbed surfactant species. The results of this test (#6) are identical to those observed in test #5, and indicate that there appears to be no evidence for fibre floating.

2.4 CONCLUSIONS

The use of Aerosol OT in the chemical treatment of dry lifted Canadian chrysotile fibre has been shown to significantly increase the degree of fibre opening. Results indicate that lower concentrations of Aerosol OT (typically 0.1 - 0.2% solution) also tend to agglomerate the -200M fraction (dust) into longer fibres.

Tests conducted to evaluate the degree of surfactant adsorption and extent of surfactant removal have shown that a one thousand-fold aqueous dilution is appropriate for removing excess non-adsorbed surfactant. There does, however, appear to be a maximum retention capacity for the fibre under study of around 12%, based upon fibre weight.

Other techniques for surfactant removal that were studied included alkali and methanol washings. The caustic treatment (1M NaOH) was found to "modify" the active chemical agent in Aerosol OT while washings with methanol showed little increase in removal efficiency as compared to simple aqueous dilution.

Final Report

In summary, although chemical treatment of asbestos fibre does show some indications of a gentle opening of the fibre bundles, the problems associated with surfactant removal and waste water control are expected to supersede any implied benefits. It should also be noted that the comparisons of fibre opening in simple aqueous media were at very low shear rates, and most similar to a simple soaking action. If one were to employ more rigorous agitation or mechanical action, the degree of fibre opening would be expected to increase dramatically.

TABLE I
AQUEOUS DILUTION OF SURFACTANT CONTACTED
CANADIAN CHRYSOTILE ASBESTOS

Test Conditions	Filtration #	Diluent Collected (g)	Total Diluent (g)	Aerosol OT Extracted (mg)		Aerosol OT Remaining (mg)
				Current	Cumulative	
0.5% Aerosol OT based upon total weight (i.e. Aerosol OT _i = 501.6 mg)	1	88.9	88.9	253.8	253.8	247.8
	2	246.8	335.7	89.3	343.1	158.5
	3	243.4	579.1	30.7	373.8	127.8
	4	500.1	1079.2	5.9	379.7	121.9
	5	491.4	1570.6	3.9	383.6	118.0
0.2% Aerosol OT based upon total weight (i.e. Aerosol OT _i = 200.5 mg)	1	94.8	94.8	56.3	56.3	144.1
	2	94.8	189.6	12.6	68.9	131.5
	3	93.8	283.4	5.8	74.7	125.7
	4	93.0	376.4	3.3	78.0	122.5
	5	93.8	470.2	2.4	80.4	120.0
	6	241.7	711.9	4.8	85.2	115.2
0.1% Aerosol OT based upon total weight (i.e. Aerosol OT _i = 99.8 mg)	7	493.2	1205.1	5.0	90.2	110.3
	8	741.2	1946.3	4.5	94.7	105.8
	1	339.0	339.0	41.0	41.0	58.8
	2	244.0	583.0	6.5	47.5	52.3
	3	245.6	828.6	4.5	52.0	47.8
	4	244.0	1072.6	2.1	54.1	45.7
0.05% Aerosol OT based upon total weight (i.e. Aerosol OT _i = 49.7 mg)	5	245.8	1318.4	1.3	55.4	44.4
	6	741.8	2060.2	2.1	57.5	42.3
0.05% Aerosol OT based upon total weight (i.e. Aerosol OT _i = 49.7 mg)	1	97.9	97.9	9.9	9.9	39.8
	2	241.3	339.2	4.2	14.1	35.6
	3	247.6	586.8	2.6	16.7	33.0
	4	492.5	1079.3	2.3	19.0	30.7
	5	493.2	1572.5	1.7	20.7	29.0

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Figure 1

Absorbance vs. λ (nm) for
Fuchsin/Chloroform Determination
of Aerosol OT Using Perkin
Elmer 35

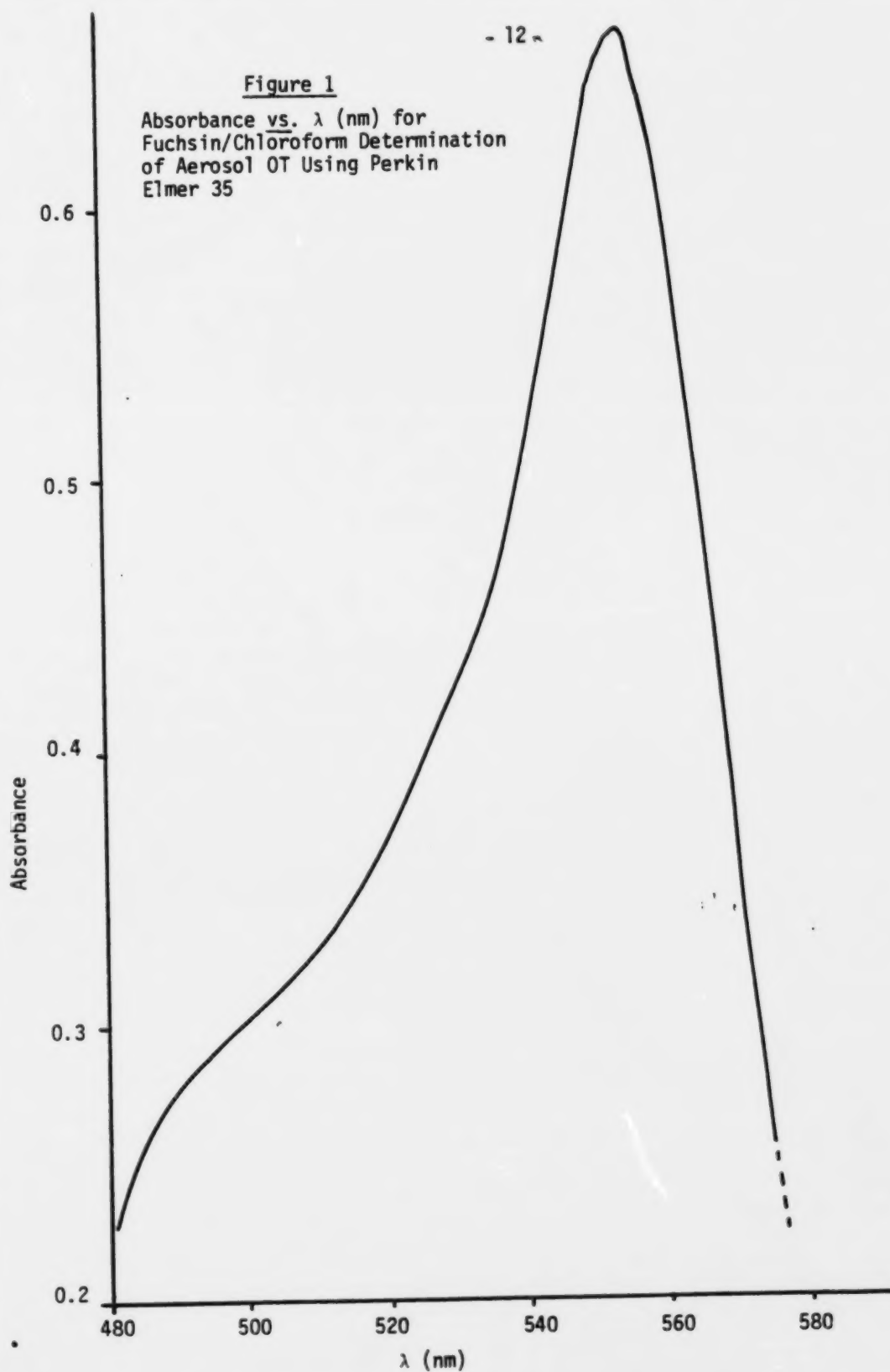


Figure 2
Calibration Curve for Fuchsin/
Chloroform Determination of Aerosol OT

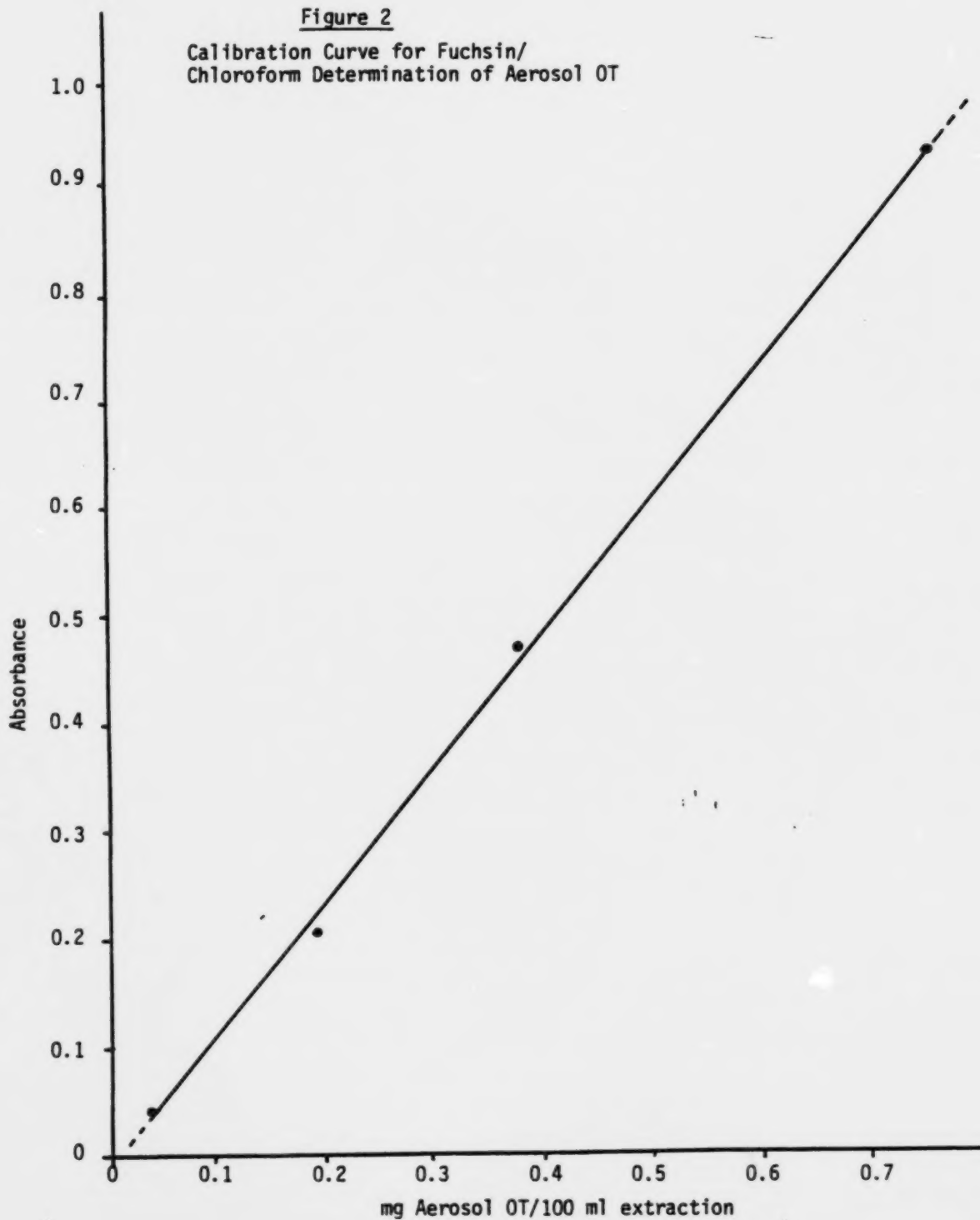


Figure 3
Removal of Aerosol OT vs. Aqueous Dilution
(Based upon 1 g of chrysotile fibre)

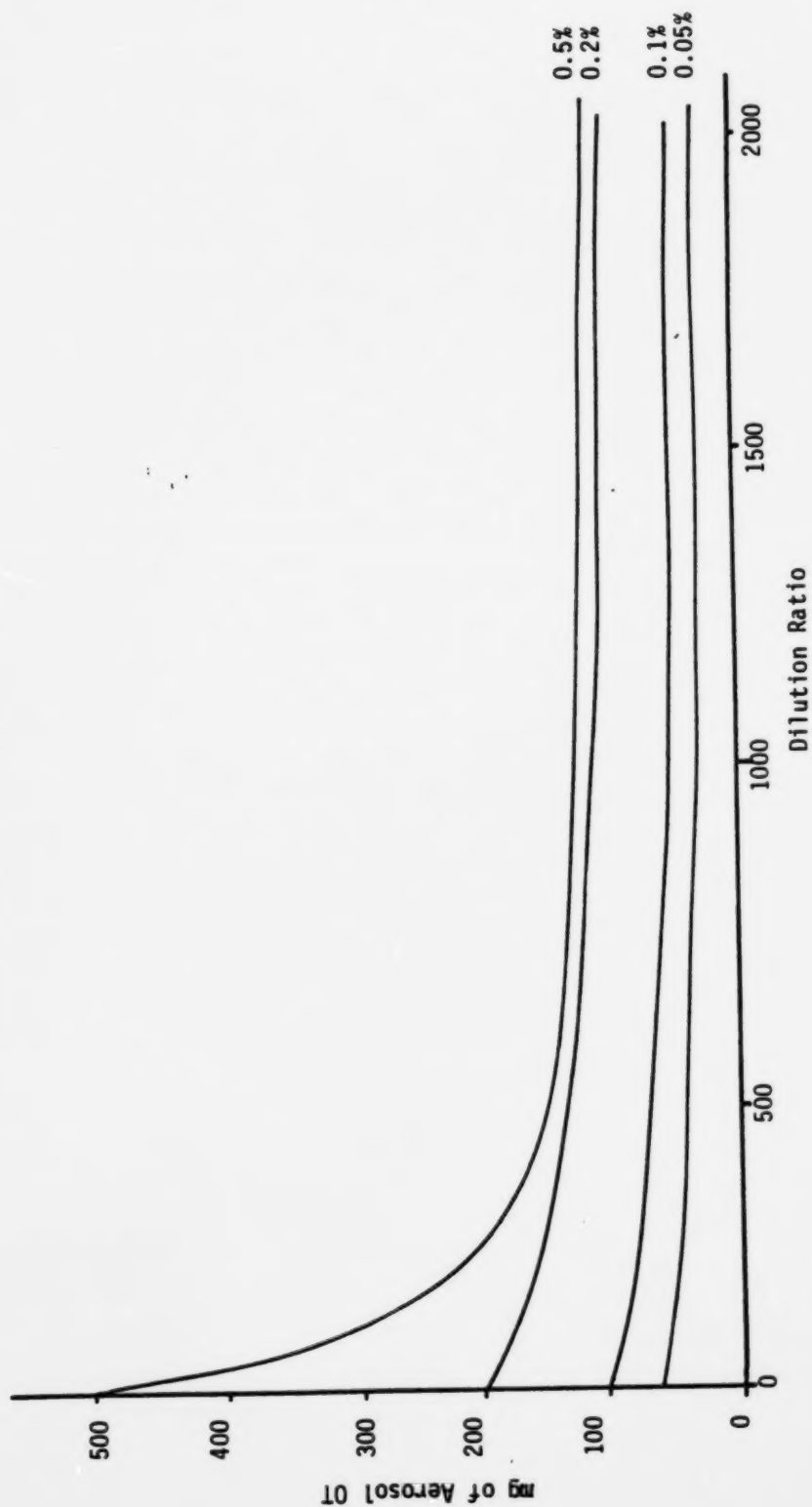
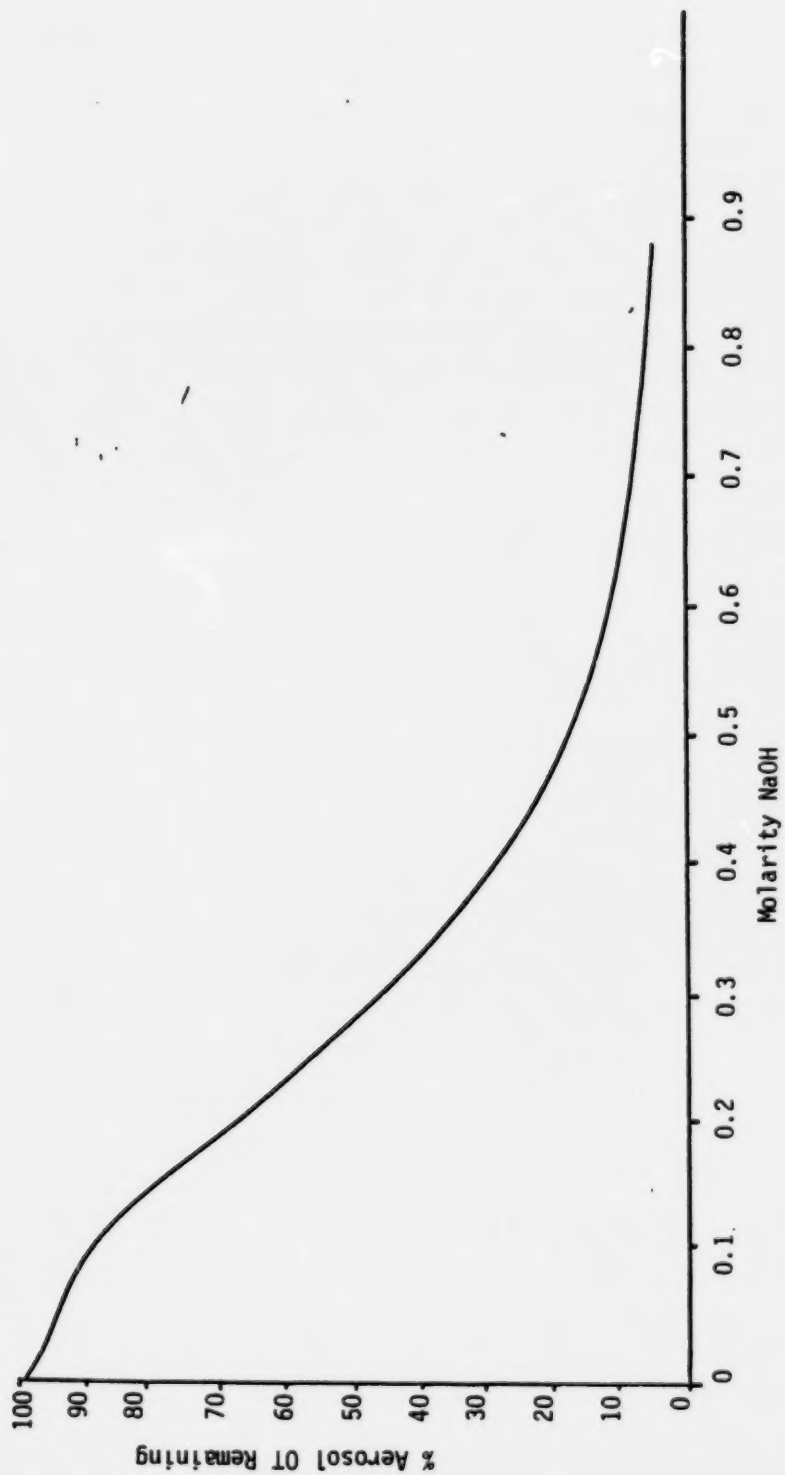


Figure 4
Alkali Conversion of
Active Aerosol OT



3. GENERAL CONCEPTS IN ASBESTOS PROCESSING

The dry milling of asbestos ore involves two distinct processes: a method of comminution and a method of fibre extraction. The conventional dry methods use a series of impaction, screening and aspiration stages to concentrate the fibre. Initial impaction stages liberate the fibre from the gangue material, while later impaction stages are used to fibrize or open the fibre so that it may be aspirated. Various screening stages prior to aspiration classify the fibre into length classes which are refined into grades in a fibre line.

The amount of impaction required to liberate the fibre is normally less than that required to sufficiently open the fibre to be aspirated. A wet asbestos comminution process involves the removal of asbestos from the ore without the use of impaction to open the fibre. Water is a more efficient transport medium than air, and therefore requires much less fibre opening to be successful.

It is recognized that traditional dry processes produce tailings that contain significant amounts of fibre which cannot be economically recovered with further dry processing. Recovery of this fibre could be economically achieved with a wet process. The rock size of the feed material would be ideal for wet processing techniques, and would require little size reduction. Initial decantation tests conducted with some tailings samples indicated good potential for complete fibre-grit separation. This is in contrast to the dry process which would require further impaction to sufficiently open the fibre. A commercial application of wet processing techniques will most likely be applied initially to fibre recovery from tailings. This study, therefore, focussed on tailing material from three Canadian asbestos producers.

The objective of the pilot scale program was two-fold. The program was designed to obtain detailed analysis and evaluation of the energy consumption of the wet process versus that of the dry process and the program would also evaluate and compare the quality and quantity of the fibre produced by each method.

3.1 Dry Processing and Equipment

In order to compare the advantages and disadvantages of the wet process over the dry one, three tailing samples were dry processed through a small core mill currently in use at Ontario Research. This circuit is shown in Figure 3-1. The material, following initial impaction in the Hazemag impact crusher, was screened on three different screen cloths: 10, 20 and 35 mesh. Intermediate impaction and aspiration stages produced three fibre lifts. The equipment used in this process was as follows.

3.1.1 Aspiration Screeners

A 60 cm x 120 cm Rotex Screener (Model No. 11) was used for all screening operations. Material fed to the screener separated into two fractions: larger or smaller than the screen cloth size used. The smaller fraction passed through the screener discharge, and proceeded to the next operation of the circuit. Material larger than the screen cloth traveled down the screener where it separated into two layers: the bottom layer consisted of rock fragments while the top layer consisted of asbestos fibre. At the discharge, the fibrous top layer was separated from the rock fragments by aspiration. The fibre was collected in a cyclone.

3.1.2 Cyclones

A 60 cm diameter air cyclone was used to collect the fibre products from all screening/aspiration operations. A rotary valve connected to the cyclone underflow was used to remove the fibre.

3.1.3 Aspiration and Dust Collection

A Wheelabrator (No. 72 Model 84) pulse type collector was used to drive all aspirators and provide all hygienic dust removal.

3.1.4 Impactors and Fibrizers

A laboratory Hazemag Impact Crusher was used with the first two screening-aspiration stages. Operating speeds (2264 rpm) remained constant throughout the flow sheet. The final fibrization stage was done with a Stedman 18", 4 row disintegrator, operating at 1916 rpm (inner cage) and 1291 (inner cage).

3.2 Wet Processing and Equipment

The agitation/decantation vessels used in the preliminary study (DSS Contract No. 03SQ.23440-3-9009) provided a batch method of separating liberated fibre from the gangue. A method was developed to continuously process the feed material (tailings from Canadian producers). The agitation/decantation vessels were replaced by a two-step process. An elutriation cone originally developed by CANMET personnel provided the initial coarse degritting, and a concentrating table provided a final degritting stage. This basic system was modified by Ontario Research during this study in order to develop a continuous process system. The basic components of this circuit were as follows.

3.2.1 Elutriation Cone

The elutriation cone was an open, low water volume, device that used an upwelling free vortex to separate the coarse gangue material from the finer gangue material and fibre (see Figure 3-2). The cone was equipped with four spray nozzles that generated a gentle swirling action in the cone. The material to be classified was fed directly to the centre of the cone where it was dispersed in the swirling water. The bottom discharge was sealed so that the water delivered by the spray nozzles discharged through the upper part only. The material supported by the upwelling, swirling water (the fine grit and fibre) was discharged through the upper port, while the rest of the material sank and was discharged as underflow. The various methods used to dispose of this underflow are described later in this chapter.

3.2.2 Concentrating Table

A Wilfley No. 13 concentrating table (2' x 4') was used for secondary degritting of the fibre. Set at a low angle, the table generated two or three products. The fibre and dust reported to the area of the table that normally produced slimes. Coarser and larger material travelled down the table and were separated from the fibre and dust. In some instances, unopened fibre, spicules and fine grit could not be distinguished by the concentrating table. This product was collected separately as a middlings, between the concentrated fibre and the reject (see Figure 3-3).

3.2.3 Dewatering and Dedusting

A drum (or trommel) screen was constructed to dewater the material at various stages of the degritting process. The tube (12" diameter x 4') was constructed out of two sizes of screens, a heavy, 1" opening screen cloth, and a 3 mesh inner screen. These screens gave the trommel sufficient rigidity to support itself without the use of internal or external frames. A third 100 mesh screen cloth was used as the inner working screen. Internal and external spray nozzles were installed to control screen blinding, and to wash the material as it was dewatered. The sprays were connected to pressure regulators, so that the spray pressures could be adjusted (see Figure 3-4).

The tube itself was mounted on a frame and connected by sprocket and chain to a variable speed motor. Funnels and catch basins were added so that both the overflow and the underflow could be collected. Rotation speed, feed rates and spray pressures of the trommel would be varied to make a product.

An alternative dewatering and dedusting system was obtained, employing a standard 18" Sweco vibratory screener with rotating spray attachments. This type of system has been used in other wet screening and dewatering operations. The manufacturer (Sweco Canada) claims to have been successful in dewatering and washing other fibrous products such as fibreglass. A schematic diagram of the Sweco system is shown in Figure 3-5.

The Sweco system was tested as a dewatering device for the table product. The fibre slurry was pumped directly to the Sweco, operating with a 100 mesh screen cloth and rotating sprays. The Sweco system was tested as a dewatering device for the table product. Rotary sprays were used as required to prevent blinding of the screen cloth and to help dedust the fibre. The 18" diameter Sweco screen used, easily dewatered the table product, although a larger unit would probably be more effective in removing the fibre.

The Sweco screener may be a viable alternative to the trommel screen. It has several advantages over the trommel. It is more compact, requiring less space to operate and several screening stages can be performed simultaneously on the same machine.

The Sweco, however, has some inefficiencies compared to the trommel. The rotating screen in the trommel results in more tumbling and mixing action, which may result in a better dedusting action. Blinding in the Sweco is more significant than in the trommel.

3.2.4 Attrition Mill

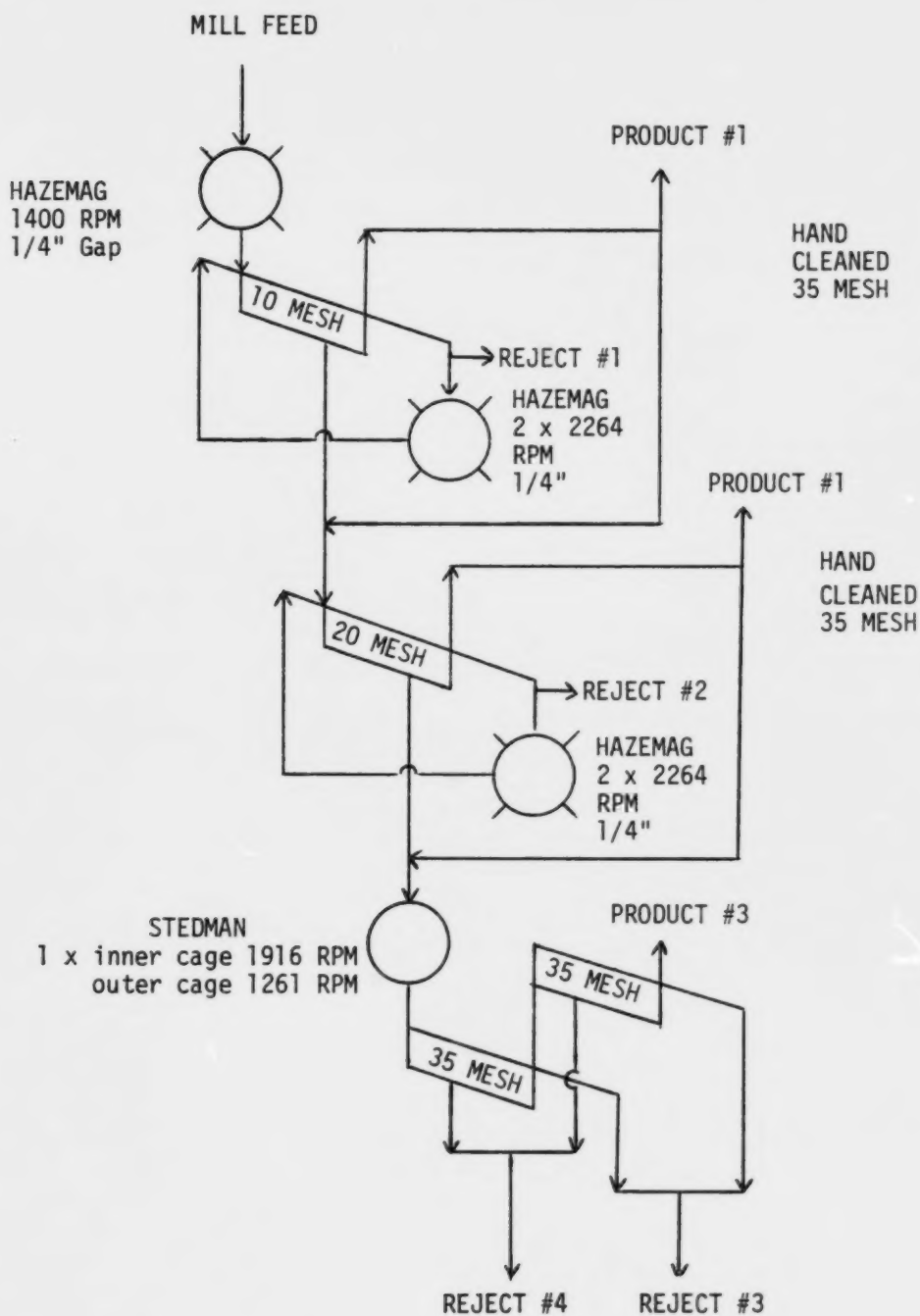
Since dry mill tailings were used as feed material for the wet circuit, little comminution was required to liberate the fibre from the gangue material. However, some mechanical reworking was required to open the fibre, in order to increase its ability to be separated from the fine gangue. A high-speed shearing impeller was used to accomplish this.

A container was designed with four vanes running down the sides to prevent any vortexing. The impeller (see Figure 3-6) was placed in the centre of the vessel, near the bottom of the container. Material was fed from the top as a thin slurry. The coarse material and unopened fibre would sink, where it would be hit by the shearing impeller. The material leaving the overflow discharge was sufficiently opened for further processing.

3.2.5 Hydrocyclone

Hydrocyclone test work was conducted with a 4" diameter Bauer "Centricleaner" and a Mozley 2" hydrocyclone. Both were used with various spigots and operating pressures.

FIGURE 3-1
SMALL CORE CIRCUIT



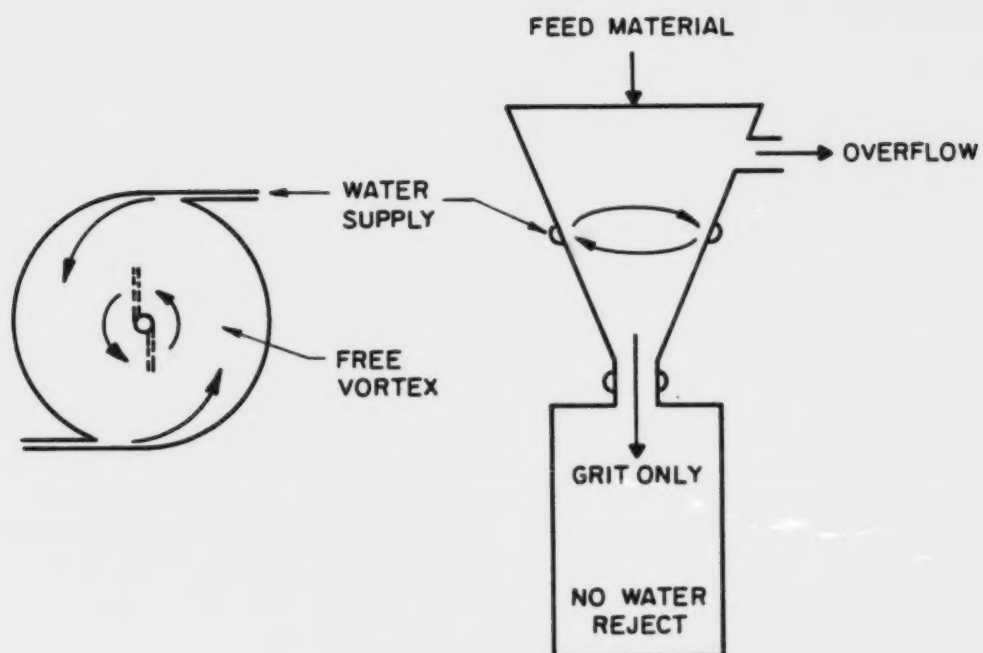
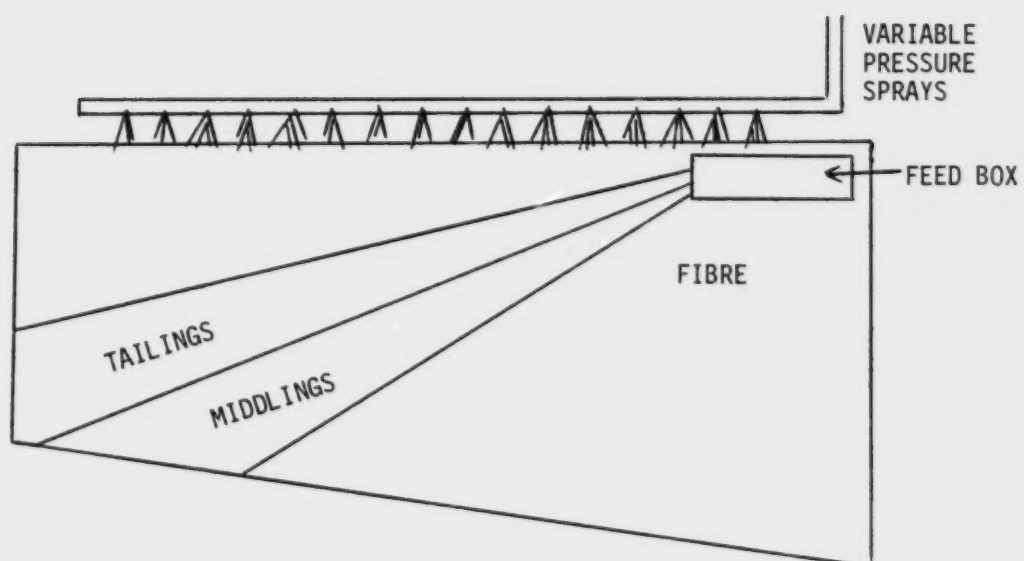


FIGURE 3-2 ELUTRIATION CONE

FIGURE 3-3
CONCENTRATING TABLE



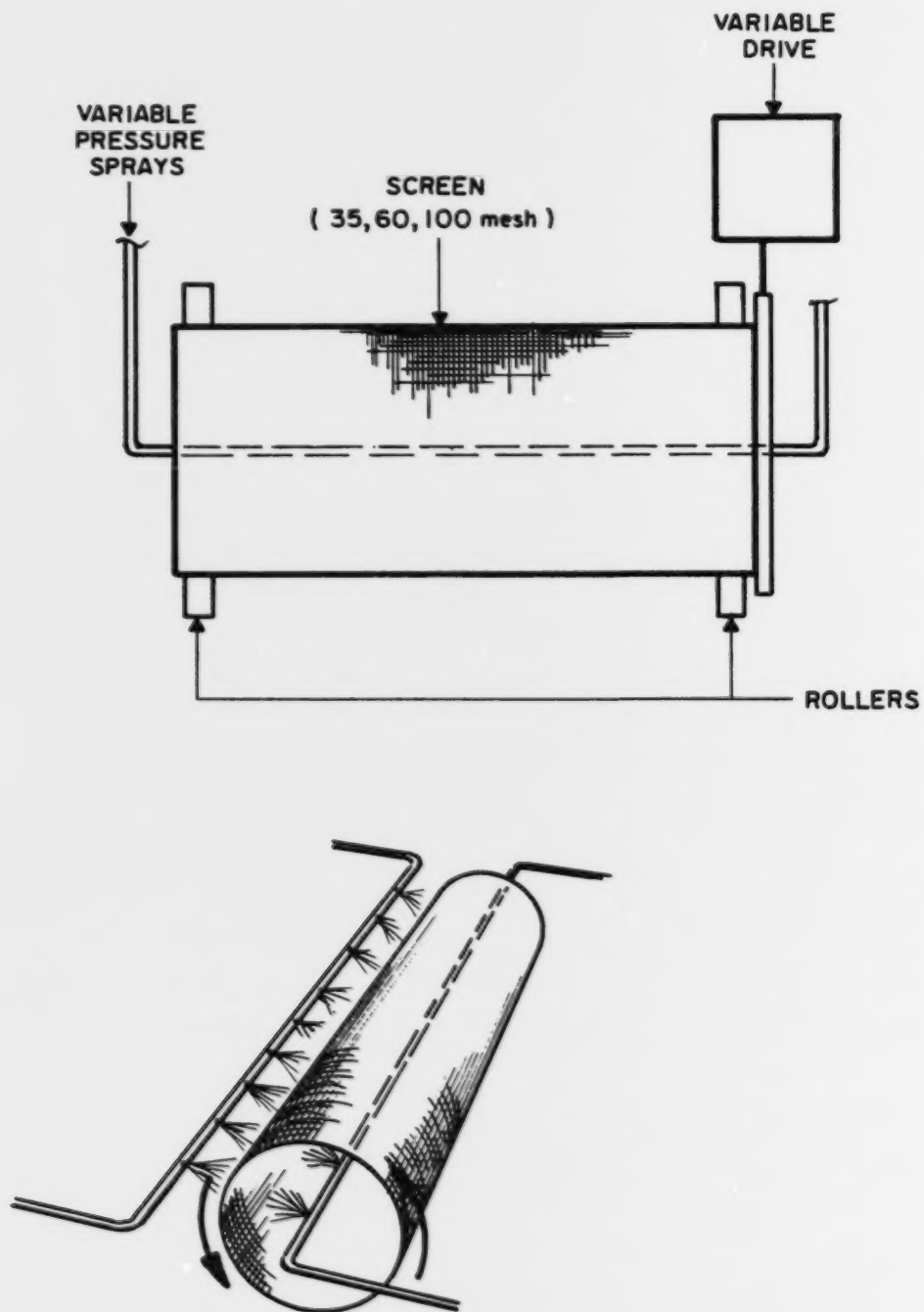


FIGURE 3-4 TROMMEL DEWATERING AND DEDUSTING SCREEN

FIGURE 3-5

SWECO DEDUSTING AND DEWATERING SYSTEM

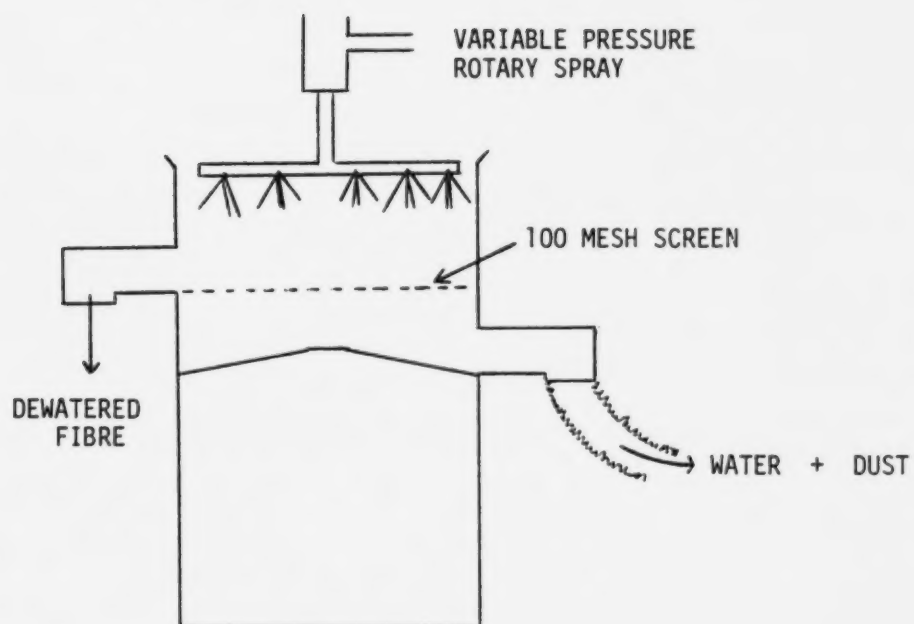
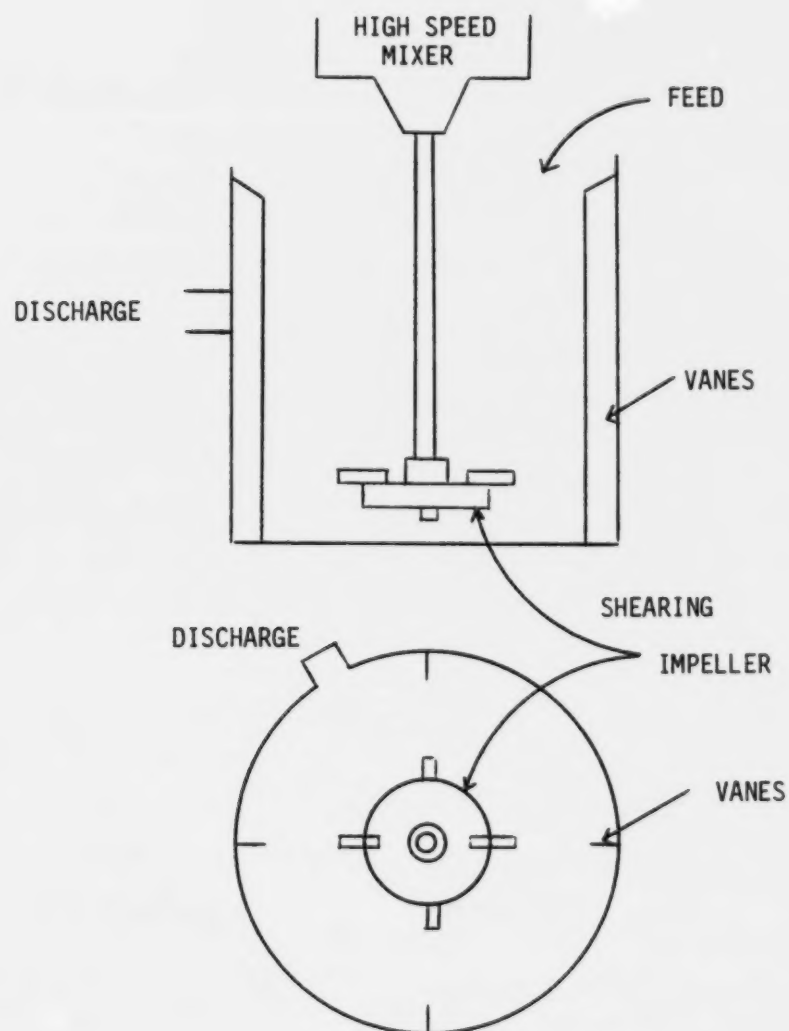


FIGURE 3-6
ATTRITION MILL



4. TESTING RESULTS FOR TAILINGS A

The first material used in this process, material A, was employed for the majority of the flowsheet development work, and was therefore subjected to considerably more testing than the other two samples. A standard set of dry and wet testing procedures were conducted on this material to assess the relative efficiencies of the wet and dry processes. Fibre recovered from both the wet and dry processes were tested by the following methods, in accordance with the chrysotile test manual (ASTM, QAMA, ISO): Wash Test, Bauer-McNett Wet Classifier, Fibre Strength Unit, and T&N Rapid Surface Area.

4.1 Dry Processing

4.1.1 Screen Analysis

In order to characterize the tailings sample, it was evaluated by various dry methods. The simplest of these was a screen analysis done on a Quebec Standard Sieve Test apparatus. A representative sample of the tailings was placed on a set of stacked square screens, sizes 1/2", 4 mesh, 10 mesh, and 35 mesh, and shaken for a standard length of time, to quickly determine the size distribution of the starting material itself. The amount of rock and fibre contained in each screen fraction was determined. These determinations gave the size distribution of the starting material, as well as the approximate length distribution of the fibre. The results of this screen analysis are shown in Table 4-1.

Tailings A was quite fine, having 75% passing the 4 mesh and approximately 55% of the material passing the 10 mesh. Total fibre recovered was 7.4%, of which the majority, (4.8%) was +35 mesh. The dust content (-200 mesh fraction) as indicated by the Wash Test, was approximately 50%. This would correspond to a group 7 fibre.

4.1.2 Dry Milling

In order to standardize the dry fibre recovery in this study, a sample of Tailings A was processed through a small core dry mill, regularly used at Ontario Research. An impact crusher, and a double cage mill was used in conjunction with 10, 20 and 35 mesh Rotex vibrating screens in order to liberate, open and recover the fibre. The circuit is shown in Figure 3-1. The mill results are shown in Table 4-2. The dry mill recovered fibre from the three lifts, corresponded to the 10, 20 and 35 mesh screening stages. These are indicated as Products #1, 2 and 3. The reject material from each aspiration stage are also shown in Table 4-2.

Tailings A had a total fibre recovery of 9% on the three screens, with the majority of the fibre recovered on the 35 mesh screen cloth. The 10 and 20 mesh fibre fractions had significant length as measured by the Bauer-McNett, Acc +14 fraction but the 35 mesh screen product was quite short. All three fibre lifts were quite dusty. Strength tests on the fibre (evaluated by the Fibre Strength Unit) indicated group 6 strength on the 20 mesh lift, and a group 7 strength on the 35 mesh lift. The three lifts were mathematically blended in order to determine a single fibre product for comparison purposes. When blended, the three lifts gave a short, dusty product, approximately a group 7 fibre. Sample calculations for this mathematical blend are shown in the Appendix following this report.

4.2 Wet Processing

Previous studies in Phase I indicated a decantation/elutriation method would be partially successful. This basic method was tested and developed using a series of flowsheets designed to study various aspects of wet milling.

4.2.1 Initial Testing

The basic elutriation cone-concentrating table system was initially developed and demonstrated by CANMET personnel. The elutriation cone was fed dry material at approximately 2.5 kg per minute and operated with a water feed of approximately 20 litres per minute. The cone overflow, consisting of fibre and fine grit, was collected in a large tank where it

was allowed to settle and then slowly decanted. This dewatering process was quite time-consuming, taking much longer than the cone process itself. The dewatered material (approximately 80 percent solids), was fed to a concentrating table. The degrittied fibre product was again partially dewatered by decanting and further dewatered by a pressure filter press. Qualitative observations indicated two main problems: the inefficiency of the dewatering system, and the presence of unclassified fibre by the concentrating table, resulted in a middlings product of fibre, grit, and fibre spicules.

4.2.2 Preliminary Flowsheet Development

The efficiency of the cone-concentrating table degrittied system, and the efficiency of the trommel screen as a dewatering and dedusting device were evaluated with a series of four flowsheets provided by the scientific authority, shown in Figures 4-1 to 4-4. Mass balances were obtained, and laboratory testing was conducted on the fibre products to assess their relative efficiency and practicality.

It had been noted that asbestos fibre tended to dedust more efficiently when mixed with grit than it does when grit free. Dust was considered to be material less than 200 mesh. Flowsheets A, B and C were designed to test this observation by using a trommel at various stages of the same basic process. The trommel would operate as both a dewatering and dedusting device. The trommel screen was described in section 3.2.3.

Flowsheet A was designed to test the efficiency of the trommel on a "grit-free" fibre sample. Dedusting and dewatering was done on the concentrating table, fibre product. The cone overflow was dewatered by decantation to assure the retention of all dust. Flowsheet B dedusted the partially degrittied material immediately after the elutriation cone. The dedusted fibre and grit was presented to the concentrating table. Flowsheet C dedusted the feed material prior to any degrittied. The dedusted (washed) material would be fed to the elutriation cone. Fibre evaluation was performed on the three flowsheets.

The efficiency of the trommel screen enabled it to be placed in all three positions in the basic flowsheet and still accomplished the dewatering and dedusting requirement. Since the placement of the trommel did not affect its efficiency, the trommel position would reflect its practical incorporation into a continuous circuit.

Flowsheet C was not considered practical from a maintenance point of view. Placing the trommel at the front end of the circuit subjected the 100 mesh dedusting screen to excessive wear. Since its placement did not significantly increase the dedusting efficiency, the increased maintenance would not be justified.

Flowsheet A had a dedusting/dewatering stage on the fibre concentrate, requiring a dewatering stage in between the elutriation cone and the concentrating table. Using the decantation method on a continuous basis was not practical, indicating that the trommel screen operating in that position, would not be the best practical solution.

Of the three, flowsheet B was the most practical. Passing the material through the trommel prior to feeding onto the concentrating table, reduced the dust content, and sufficiently dewatered the resultant material. This provided a continuous dedusting and dewatering stage and a materials transfer system, between the cone and table.

The only significant problem associated with flowsheet B was the capacity of the concentrating table. The table required a low operating angle to provide optimum fibre gangue separation. This low angle, however increased the residence time of the material on the concentrating table, causing the table to be the slowest single operation in the circuit. The high residence time of the gangue material tended to flood the table.

Flowsheet D evaluated the necessity of the elutriation cone in fibre grit separation. This flowsheet attempted to generate a reject and thereby eliminate the use of the cone. A 3/16" dry scalp was taken from the feed material. The oversize was passed through the Flowsheet A circuit, while the undersized material was dedusted in the trommel and

fed directly onto the concentrating table. The fibre content of the +3/16" scalp was negligible when compared to the fibre content of the undersize fraction. The undersize fraction which was fed directly to the concentrating table, accentuated the grit problem. The table was immediately flooded without the prior elutriation cone degritting stage.

It was concluded that of the four flowsheets provided by the scientific authority, Flowsheet B had the best potential to be developed into a continuous process. Tables 4-3 and 4-4 show the average mass balances of the four flowsheets evaluated.

The four flowsheets evaluated had the same basic components, although the dedusting procedures were somewhat different. The basic principal of these flowsheets was the removal of the coarse grit using the elutriation cone, and the fine grit using the concentrating table. Dust and water were removed using the trommel.

The concentrating table operation gave three products: a fibre concentrate, a middlings and a tailings. The middlings product generated by the table contained fibre, unopened fibre spicules and some finer grit. Free, opened fibre was recovered in the middlings to insure as grit free, a fibre concentrate as possible.

In these initial tests, the middlings product was dried, passed through the dry laboratory impactor and retabled. Mass balances in these flowsheets indicate an initial product and tailing (Product #1, Tailing #1) produced by the first pass of the material over the concentrating table. The reworked middlings were passed over the table a second time, giving three more products (Product #2 etc.)

In flowsheet D, the tailings material was split into two fractions, (plus and minus 3/16"). Separate passes over the concentrating table gave two table products designated Product #1. They were differentiated by screen fraction. Middlings from the two fractions were combined and reworked, giving a single product.

The material splits on the elutriation cone were essentially the same for flowsheets A, B and C. The initial pass over the concentrating table produced varying results. Flowsheet A had the largest fibre recovery, while B and C had quite similar ones. The amount of tailings generated was a function of the position of the splitters on the concentrating table, the feed rate, and the amount of water added to the table. These conditions were varied slightly with each run to best separate the fibre, resulting in various amounts of tailing and middlings product, which were sometimes indistinguishable.

Impacted middlings, processed through the laboratory impact crusher or the laboratory attrition mill, were repassed over the concentrating table. The three flowsheets have similar table products with the exception of a significantly higher fibre recovery on flowsheet B. This may not be a significant result since small samples (approximately 50 kg) were used in the individual tests. Inhomogeneities in the tailings material may explain these variations.

Flowsheet D followed a significantly different process, and therefore could not be compared to the other three by fibre recovery alone. The total recovery was 3.1%, which was significantly smaller than the other three. The tailings and middlings, contained fibre due to the grit flooding problems on the concentrating table.

The quality of the individual fibre products are summarized in Table 4-5. The samples are listed by flowsheet and test number. The "Product" indicates the pass over the concentrating table that produced the product (i.e. first pass = Product #1, second pass = Product #2).

The surface area for all products ranged from 4,000 cm²/g to 9,000 cm²/g. There was no consistent pattern to the surface area in the samples produced. The variability of the surface area reflects the range of the degree of fibrization of the tailings material, but may also be due to the amount of agglomeration or matting of the fibre during the drying process.

The T&N Rapid Surface Area test required a dry fibre sample in the air permeability chamber. This required the fibre to be processed through a given wet circuit to be dried, which caused large agglomerations. The agglomerations were partially opened by hand, and then fed through a small hammer mill to fluff up the fibre. The amount of opening done in the hammer mill may have been influenced by the size of the agglomeration fed into it. Large pieces may have only been broken up, while small pieces were broken up and fibrized before they passed through.

Fibre length distributions of the various samples, as measured by the Bauer-McNett Classifier, varied quite significantly from sample to sample, suggesting that the samples were somewhat inhomogeneous. This would be expected in a tailings product. The individual samples, however, generated two products of very similar length distributions, suggesting that a single product was generated by these circuits.

In order to better evaluate the length distributions of these products, the various products of the four different flowsheets were mathematically blended, and then dust adjusted to a common dust level. Sample calculations are given in the appendix following this report. Table 4-6 and 4-7 lists these results. Within the error limits of the Bauer-McNett Classifier, flowsheets A, B and C produced fibre of the same length distributions. Flowsheet D produced somewhat shorter fibre. Fibre recoveries from A, C and D were virtually the same, while flowsheet B recovered a slightly smaller amount of fibre.

Fibre Strength Unit measurements were obtained for the various products in the flowsheets. These were done to determine whether or not two separate products could be made from the concentrating table. The reworked middlings were tested separately and it was found that there was essentially no difference between them and the first product when measured by length or strength. The two table products could not be considered to be different grades.

4.2.3 Hydrocyclone Flowsheet

A continuous process involving the basic flowsheet design necessitated a balance between the capacity of the cone and the table. The cone required approximately 18 l/min. of water to generate enough of a free vortex to classify the fibre as overflow. With a dry cone feed of approximately 2.5 lb./min., the overflow slurry was approximately 5% solids. This was dewatered to approximately 40 - 50% solids, which was fed to the table at approximately 0.5 kg of solids per minute. Depending on the amount of grit presented to the table, the feed rate was often beyond the capacity of the table. Rather than slow down the cone, other methods of speeding up the degritting process were attempted.

A 4" diameter Hydrocyclone replaced the concentrating table in Flowsheet E (see Figure 4-4). A hydrocyclone of this size was needed to accept the size of grit being passed as overflow by the elutriation cone. The hydrocyclone was operated at 25 psi and fed a slurry of less than 5% solids. A grit-free fibre product was generated as hydrocyclone overflow.

Water consumption and handling problems encountered in the previous circuits were greatly increased with the hydrocyclone. Being a continuous or semi-continuous process, continuous dewatering of the hydrocyclone product was essential. This was accomplished with a direct feed into the trommel screen. A second pass through the trommel was required to dedust it.

Although the hydrocyclone overflow produced very clean (grit-free) fibre, the recoveries were very low. Much of the fibre was discharged as hydrocyclone underflow, and was therefore not recovered. The underflow was passed through the attrition mill to further open it, and then repassed through the hydrocyclone, with no significant increase in fibre recovery. A second 2" hydrocyclone was installed, which was used to process the 4" hydrocyclone underflow, but was only partially successful. Much fibre was still rejected (see Table 4-8 and 4-9).

Tables 4-8 and 4-9 list the mass balance from the circuit tested as well as the quality of the fibre recovered. The elutriation cone underflow was dried and weighed, while the overflow was measured by difference. The products generated by the hydrocyclones are listed as hydrocyclone overflows.

The fibre recovery from this type of circuit was significantly less than any of the previous flowsheets evaluated. Under normal situations the 2" hydrocyclone underflow would be a reject, but in this case it contained a significant amount of fibre.

The two products recovered contained significantly more dust than fibre products from other circuits. This may have resulted because of the openness of the fibre. At $25,000 \text{ cm}^2/\text{g}$, the fibre may have resisted dedusting in the trommel. Mathematically blended and dedusted, the hydrocyclone fibre product tends to be slightly longer than the other fibre products, but the recovery is only a fraction of the other flowsheets.

A degritting system using the hydrocyclone has the potential to be a viable alternative to the table. Higher operating pressures and, possibly, other vortex finders are required to increase the hydrocyclone overflow and, therefore, recovery.

The hydrocyclone system is potentially a much faster process, but it has disadvantages. Large volumes of water at high pressures are required, which is far more energy intensive than the gravity feed system possible with the table. Control and adjustments to the hydrocyclone system are also much more difficult. Intermediate products cannot be examined since all classification is done in the hydrocyclone.

An additional result of the hydrocyclone process may be a disadvantage, or an advantage, depending on the preference of the consumer. Fibre concentrated by the table had a surface area ranging from $3,600 \text{ cm}^2/\text{g}$ to $9,000 \text{ cm}^2/\text{g}$, which was in sharp contrast to the hydrocyclone product at a surface area of $25,000 \text{ cm}^2/\text{g}$. Although a

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minimal amount of testing was done on the hydrocyclone, the surface area is thought to be a good estimate of a hydrocyclone product. The fibre had been passed through the pump and other circuits without substantial opening. In order to minimize fibre destruction in the hydrocyclone system, the fibre was not processed as a re-circulating load. The majority of the fibre recovered was passed through the hydrocyclone a single time. The rest of the fibre recovered was also processed through the attrition mill and two other hydrocyclones. The higher surface areas produced by this type of circuit may be a factor in its ultimate use.

4.2.4 Two Cone Flowsheet

If the concentrating table were to be used in a continuous flowsheet, the tendency of the grit to choke the table would have to be eliminated or substantially reduced. To achieve this, further degritting of the elutriation cone overflow was required before feeding the table. Decreasing the flow in the elutriation cone increased the grit reject, but larger amounts of fibre were lost to tailings. Decreasing both the volume of water and the dry feed was not a viable solution. The elutriation cone was not able to degrit the fibre sufficiently because of the decreased elutriation effects of the vortex generated by the sprays.

A second cone was constructed which was more shallow and wider than the first, and therefore required less water to elutriate the feed material. This second cone was incorporated into the basic flowsheet behind the first. The overflow from the first cone was dewatered and fed to the second cone which provided a second grit reject fraction. The overflow from the second cone was sufficiently degrittled to allow a continuous feed to the table. Tests conducted with a direct feed to the table from the second cone, and a thickened feed, suggest that a thickening would be beneficial at this stage. This circuit was designated Flowsheet F, (Figure 4-6).

The two-cone table circuit was the most efficient method of fibre recovery. The double cone system with the intermediate dewatering (and partially dedusting) stage sufficiently degrittled the fibre, enabling a continuous feed to the concentrating table. Thickening of the second cone overflow was done in a thickener, which was only partially successful. Tables 4-10 and 4-11 list the mill data and quality of the fibre.

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The mass balance given in Table 4-10 shows a slightly greater reject (underflow) in the first elutriation cone than was previously encountered with the material. The second elutriation cone rejected only a small percentage of the material fed into it. An exact amount could not be determined because of the removal of dust by the trommel in between the two cones. The two table passes (the first pass, and the reworked middling) were combined, and are listed as a single mass balance. The trommel weight was measured by difference.

The quality of the fibre products are listed in Table 4-10. The fibre recovery was good, and its length was quite significant. Dust levels were very low, at approximately 8%. The mathematical composite blend showed this to be a long clean fibre. The blend was mathematically adjusted in order to compare it to the other circuits.

A two-cone elutriation circuit is potentially an energy efficient method of asbestos production. The main energy consumers are the trommel screen, the concentrating table, and the attrition mill. Ore can be fed at the front end and gravity feed systems can be used through the circuit. A high fibre recovery and a more efficient continuous system made the two-cone flowsheet the choice for further work and development.

TABLE 4-1SCREEN ANALYSIS OF TAILINGS A

<u>Screen Fraction</u> <u>(mesh)</u>	<u>Total</u> <u>(Wt. %)</u>	<u>Fibre</u> <u>(Wt. %)</u>	<u>Wash Test</u> <u>(Wt. % -200)</u>
1/2"	2.7	-	-
4	15.2	-	-
10	31.7	0.9	53
35	27.6	4.8	45
-35	22.8	1.7	*28

* The fibre sample was very gritty, indicating a higher dust content in the fibre itself.

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TABLE 4-2
DRY MILL DATA

	Wt. (Kg)	Wt. %
Reject #1	28.7	31.0
Reject #2	17.2	18.6
Reject #3	7.7	8.3
Reject #4	30.7	33.1
Product #1	.21	0.2
Product #2	1.42	1.5
Product #3	<u>6.73</u>	<u>7.3</u>
TOTAL	92.66	100.0

Sample	Surface Area (cm ² /g)	Bauer-McNett (Wt. %)						Rec.	FSU
		Acc.							
		+4	+14	+14	+35	+200	-200		
Dry Process									
Product #1	4,400	18	17	34	8	17	41	0.2	-
Product #2	3,600	7	13	20	16	17	47	1.6	84
Product #3	9,500	1	3	4	8	24	64	7.2	59
Composite Blend	-	3	5	8	10	23	60	9.0	-

Mathematically Dust Adjusted									
Product #1	-	24	22	46	11	22	20	0.1	-
Product #2	-	10	20	30	25	26	20	1.1	-
Product #3	-	2	6	8	18	54	20	4.1	-
Composite Blend	-	6	10	16	20	44	20	4.5	-

TABLE 4-3

AVERAGE MASS BALANCES FOR THE FLOWSHEET A, B AND C TESTS

Flowsheet	Elutriation Cone	Concentrating Table		Concentrating Table Products			Trommel* Unders Wt%
	Wt% Cone* Overflow	Cone Underflow	Products Products#1	Wt% Tailings#1	(reworked Middlings) Product#2	Wt% Middling#2 Tailing#2	
Flowsheet A (see Fig.4.1)	36.8	63.2	5.0	13.3	0.5	5.5	11.0
Flowsheet B (see Fig.4.2)	36.8	63.2	3.5	16.0	0.5	—	15.6
Flowsheet C (see Fig.4.3)	38.2	61.8	3.8	12.2	0.5	4.5	16.1

* Wt% of Cone overflow and trommel unders measured by difference.

TABLE 4.4

AVERAGE MASS BALANCES FOR THE FLOWSHEET-D TESTS
(see Figure 4.4)

3/16 Undersize 78.8%				3/16 Oversize 21.2%					Trommel* Unders
Concentrating Table Products WT%		Elutriation Cone (WT%)		Concentrating Table Products (WT%)		Concentrating Table** Products (reworked Mids)(WT%)			
Product	Tailings	Cone*	Cone	Product	Tailings	Product	Middlings	Tailings	
#1	#1	Overflow	Underflow	#1	#1	#2	#2	#2	
2.0	52.6	1.1	20.1	0.2	0.6	0.9	3.8	2.1	17.7

* WT% of cone underflow and trommel unders measured by difference.

** Reworked middlings are a combination of both oversize and undersize 3/16" screen fractions.

TABLE 4-5

PRELIMINARY TEST RESULTS ON WET PROCESSED TAILINGS

Sample	Product	Surface Area (cm ² /g)	Bauer-McNott (Wt. %)							FSU	% Recovery
			Acc.								
			+4	+14	+14.	+35	+200	-200			
A-1	#1	4,200	10.9	11.0	21.9	20.5	50.2	7.4	101	3.1	
	#2	-	12.8	10.6	23.4	15.4	43.9	17.3	-	0.7	
A-2	#1	7,100	2.4	3.8	6.2	9.8	45.0	39.0	84	4.7	
	#2	-	2.8	5.0	7.8	12.2	59.8	20.8	-	0.2	
A-3	#1		1.7	3.5	5.2	10.4	48.3	36.1	-	-	
	#1 second dedust	7,300	3.1	5.2	8.3	13.4	57.3	20.9	101	3.4	
	#2	5,300	1.9	2.9	4.8	0.7	23.6	70.9	-	0.5	
A-4	#1	-	9.4	6.6	16.0	18.5	47.4	18.1	-	5.7	
	#2	-	9.8	10.2	20.0	16.4	48.9	14.6	-	0.4	
A-1+A-2 Blend	#2 blend	4,100	8.1	9.3	17.4	12.8	51.8	18.1	96	-	
B-1	#1	9,000	-	-	-	-	-	-	-	2.6	
	#2	-	3.5	6.2	9.7	15.7	61.5	13.1	-	0.4	
B-2	#1	5,200	5.4	6.7	12.1	14.1	54.0	19.8	97	4.4	
	#2	-	5.1	7.1	12.2	10.3	36.4	41.1		0.6	
B-1+B-2 Blend	#2 blend	4,300	4.1	6.7	10.8	10.3	50.9	28.0	90	-	
C-1	#1	4,100	8.2	10.8	19.0	17.9	43.5	19.6	101	4.6	
	#2	-	10.3	8.9	19.2	19.9	46.1	14.8		0.6	
C-2	#1	-	5.3	7.8	13.1	15.4	54.2	17.2	93	2.9	
	#2	-	3.1	4.7	7.8	12.7	62.6	16.9		0.5	
C-1+C-2 Blend	#2 blend	5,500	5.1	8.1	13.5	16.2	54.3	16.0	98	-	
D-2	#1	7,300	3.3	4.5	7.8	10.9	36.5	44.8	96	3.3	
	#2	-	-	-	-	-	-	-	-	-	
D-3	#1	8,400	2.7	4.6	7.3	16.6	59.9	16.1	105	2.8	
	#2	5,200	3.9	6.6	10.5	14.0	55.8	19.6	98	0.9	
D-4	#1	6,800	4	7	11	18	59	13		2.4	
	#2	-	4	7	11	14	60	15		-	

TABLE 4-6
FIBRE LENGTH AND RECOVERY COMPARISONS

Sample	Bauer-McNett (Wt. %)						Rec. (%)
	+4	+14	Acc. +14	+35	+200	-200	
<u>Mathematically Blended</u>							
Flowsheet A							
Product #1	7	6	13	15	49	23	4.23
Product #2	8	8	16	11	41	32	0.45
Composite							
Blend	7	6	13	14	48	25	4.68
Flowsheet B							
Product #1	5	7	12	14	54	20	3.50
Product #2	5	7	12	13	46	29	0.50
Composite							
Blend	5	7	12	14	53	21	4.00
Flowsheet C							
Product #1	7	10	17	17	48	18	3.75
Product #2	7	7	14	17	54	15	0.55
Composite							
Blend	7	10	17	17	49	17	4.30
Flowsheet D							
Product #1	3	5	8	15	52	25	4.25
Product #2	4	7	11	14	58	17	0.45
Composite							
Blend	3	5	8	15	53	24	4.70

TABLE 4-7
FIBRE LENGTH COMPARISONS

Sample	Bauer-McNett (Wt. %)						Rec. (%)
	+4	+14	Acc. +14	+35	+200	-200	
<u>Mathematically Dust Adjusted</u>							
Flowsheet A							
Product #1	7	6	13	16	51	20	4.07
Product #2	9	9	18	13	48	20	0.38
Composite							
Blend	7	5	14	15	51	20	4.45
Flowsheet B							
Product #1	5	7	12	14	54	20	3.50
Product #2	6	8	14	15	42	20	0.44
Composite							
Blend	5	7	12	14	54	20	3.94
Flowsheet C							
Product #1	7	10	17	17	47	20	3.8
Product #2	7	7	14	16	51	20	0.54
Composite							
Blend	7	10	16	16	48	20	4.38
Flowsheet D							
Product #1	3	5	8	16	55	20	3.90
Product #2	4	7	12	13	56	20	0.47
Composite							
Blend	3	5	8	16	56	20	4.45

TABLE 4-8

FLWSHEET E TEST RESULTS
HYDROCYCLONE TEST CIRCUIT
(See Figure 4-5)

Elutriation Cone (WT%)		4" Hydrocyclone (WT%)		2" Hydrocyclone (WT%)		Trommel*
Overflow	Underflow	Overflow	Underflow	Overflow	Underflow	Unders (WT%)
40.5	59.5	1.0	--	-.1	26.6	12.8

* Trommel unders are measured by difference

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TABLE 4-9

FLWSHEET E
FIBRE QUALITY TEST RESULTS

<u>Sample</u>	Surface Area (cm ² /g)	Bauer-McNett (Wt %)						Rec (%)
		<u>+4</u>	<u>+14</u>	<u>Acc.+14</u>	<u>+35</u>	<u>+200</u>	<u>-200</u>	
Flowsheet E								
Product #1	25,000	6	6	12	7	29	53	1.0
Product #2	-	3	8	11	13	54	22	0.1
Composite	-	6	6	12	8	31	49	1.1
Blend								

Mathematically Dust Adjusted

Flowsheet E								
Product #1	-	10	10	20	12	48	20	0.6
Product #2	-	3	8	11	13	55	20	0.1
Composite	-	9	10	19	12	49	20	0.7
Blend								

TABLE 4-10
FLOWSHEET F TEST RESULTS
TWO-CONE TABLE CIRCUIT
(see Figure 4-6)

Elutriation Cone I (WT%)		Elutriation Cone II (WT%)		Concentrating Table (WT%)			Trommel* Unders
Overflow	Underflow	Overflow	Underflow	Product	Middlings	Tailings	
*							
26.0	74.0	—	2.6	5.4	0.7	12.8	9.3

* WT% measured by difference

TABLE 4-11

FLWSHEET F
FIBRE QUALITY TEST RESULTS

<u>Sample</u>	Surface Area (cm ² /g)	Bauer-McNett (Wt %)						Rec (%)
		<u>+4</u>	<u>+14</u>	<u>Acc.+14</u>	<u>+35</u>	<u>+200</u>	<u>-200</u>	
Flowsheet F								
Product #1	4,600	6	10	16	19	56	9	3.9
Product #2	3,600	12	16	28	16	50	6	1.5
Composite								
Blend	-	8	12	20	18	54	8	5.4

Mathematically Dust Adjusted

Flowsheet F								
Product #1	-	5	9	14	17	49	20	4.4
Product #2	-	10	13	23	14	43	20	1.8
Composite								
Blend	-	7	10	17	16	47	20	6.2

FIGURE 4-1
FLOWSHEET A

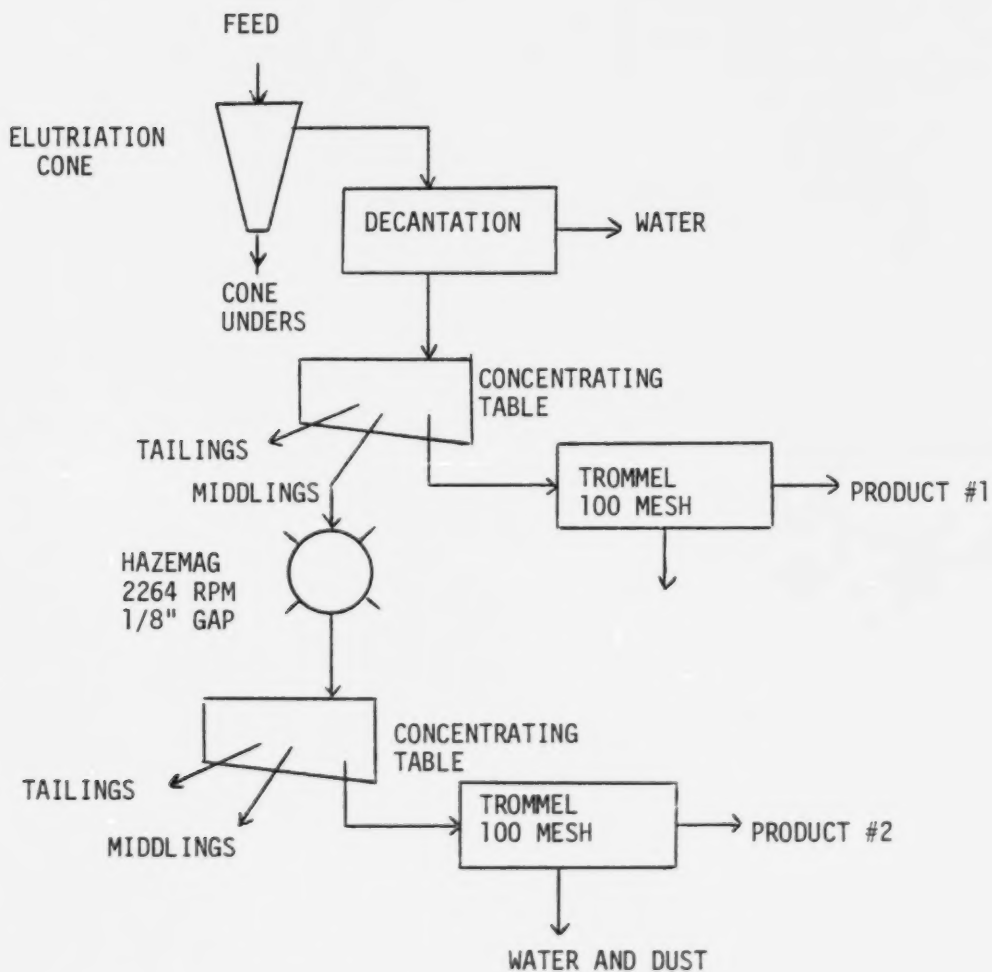


FIGURE 4-2

FLWSHEET B

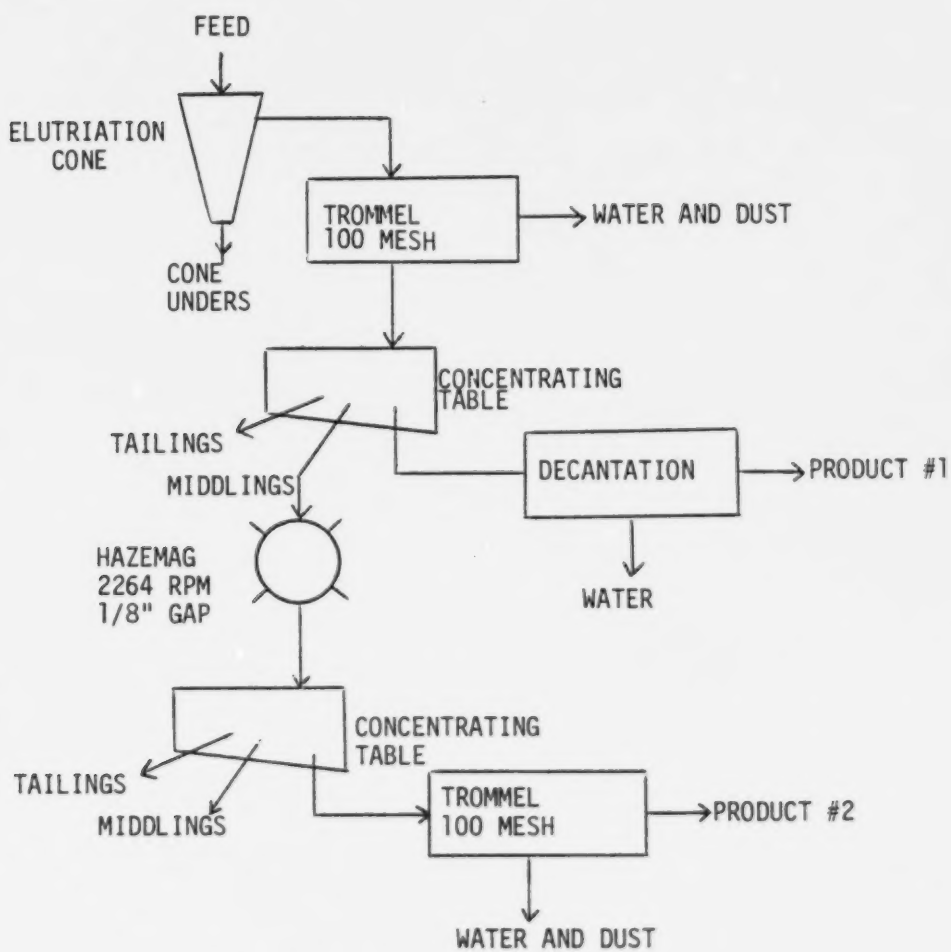


FIGURE 4-3
FLOWSHEET C

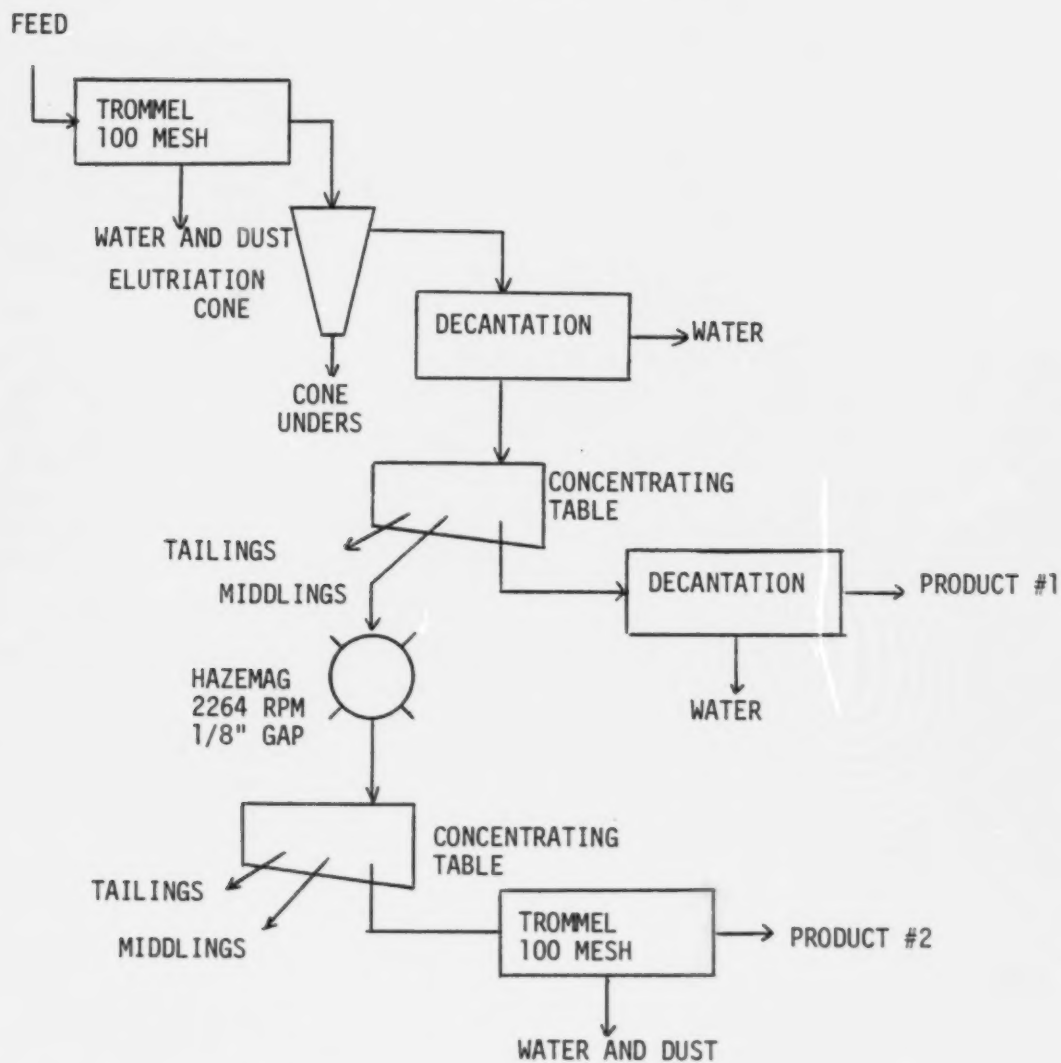


FIGURE 4-4
FLOWSHEET D

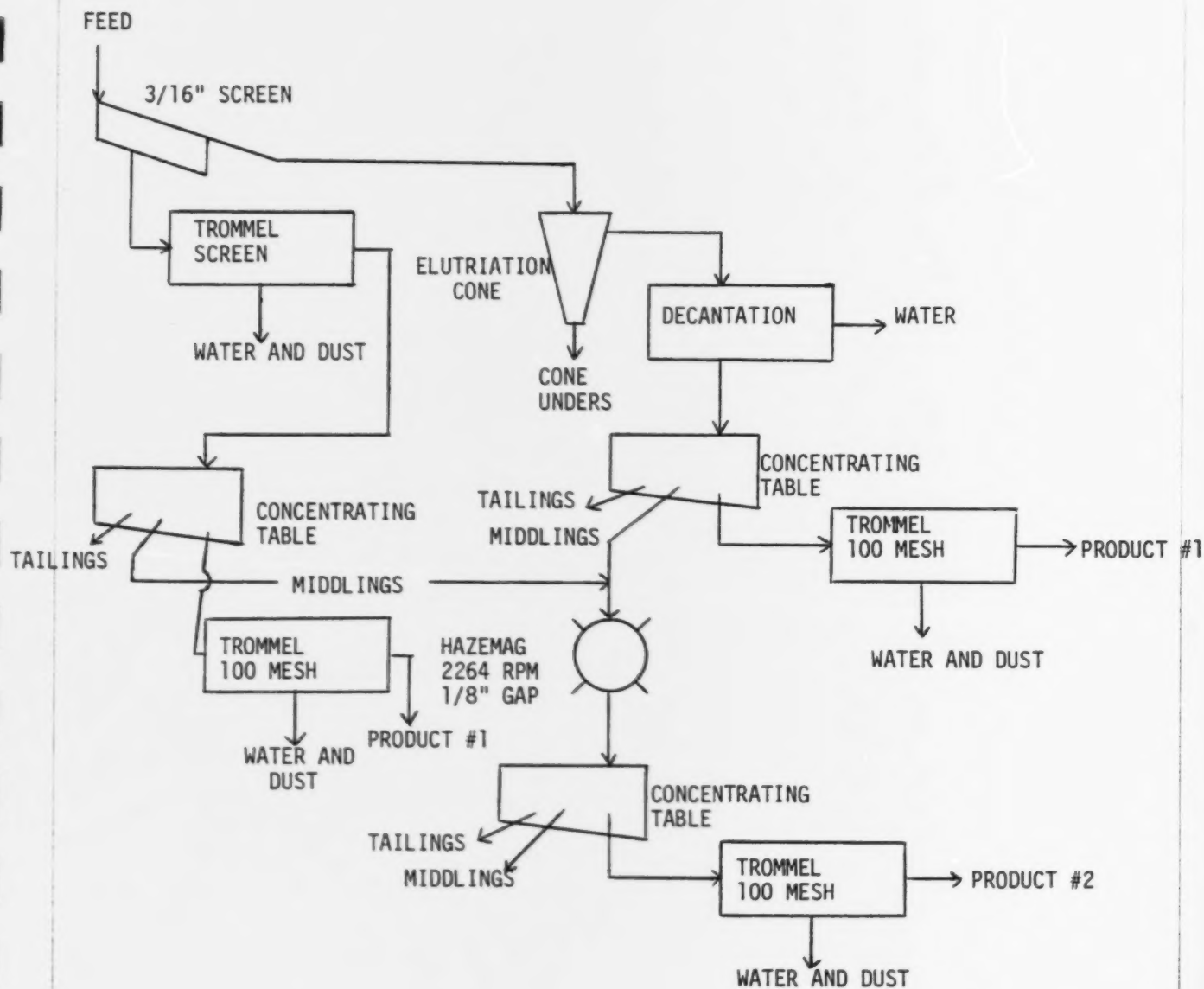


FIGURE 4-5
FLOWSHEET E
HYDROCYCLONE CIRCUIT

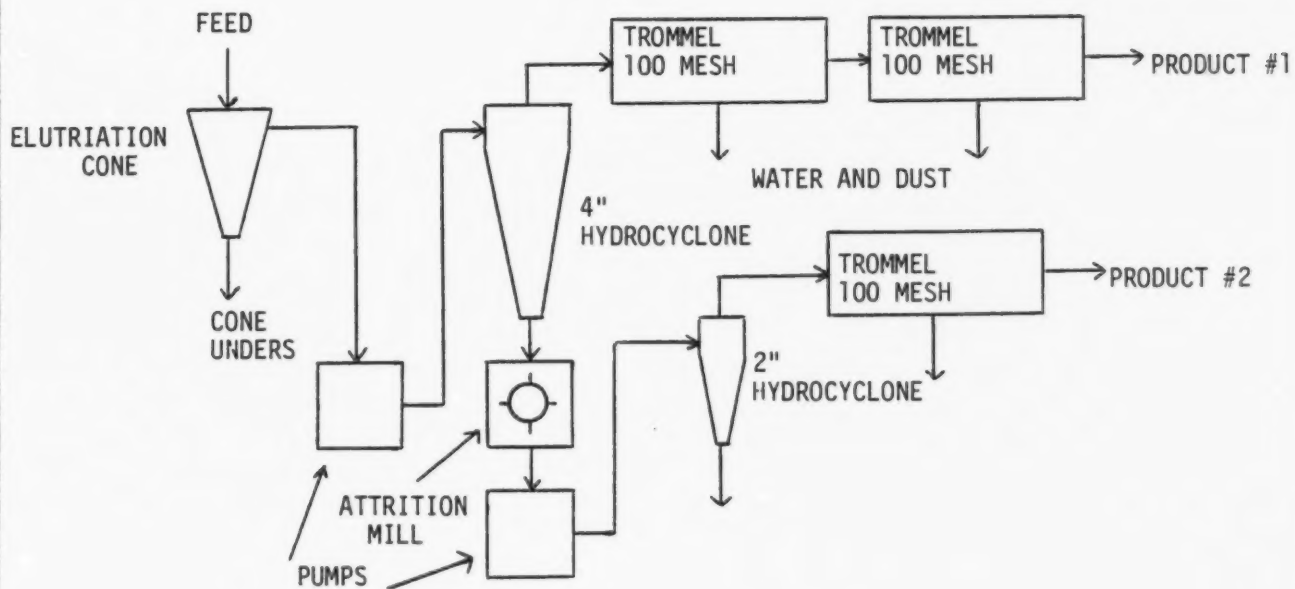
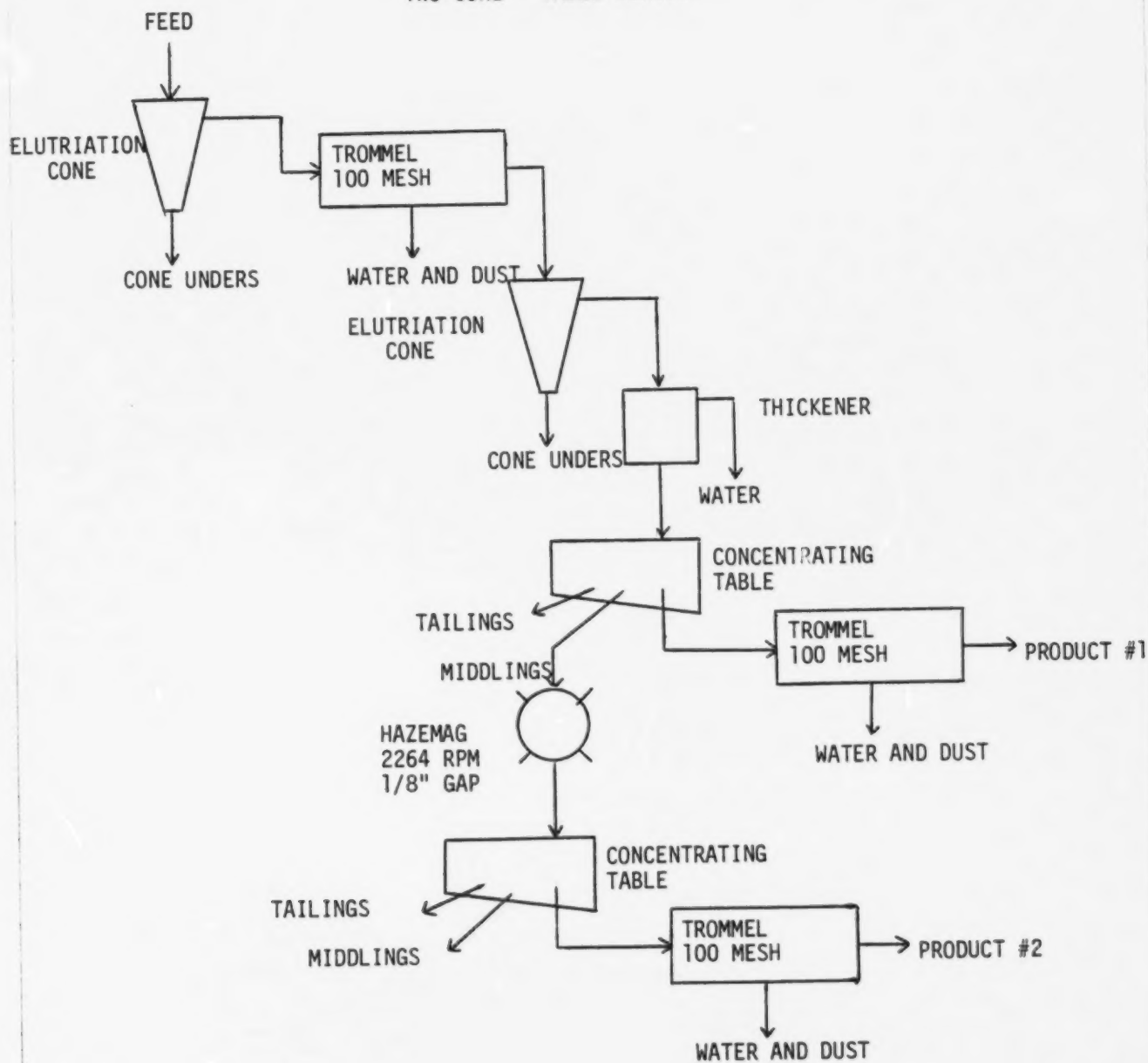


FIGURE 4-6
FLOWSHEET F
TWO-CONE - TABLE CIRCUIT



5. TESTING RESULTS FOR TAILINGS B

The two-cone circuit that was developed using the Tailings A material was the basic circuit used in the wet/dry milling comparisons made on the Tailings B material. Dry milling and testing procedures remained the same, but minor modifications to the wet circuit helped make it a more continuous and practical system. Some minor modifications were also required in order to properly classify the new material.

5.1 Dry Processing

5.1.1 Screen Analysis

A size distribution of gangue and fibre was determined for Tailings B by the same method used in Tailings A. The screen analysis showing rock and fibre distribution is shown in Table 5-1. Approximately 90% of the material passed 4 mesh and 70% passed the 10 mesh. The fibre recovered (5.9%) was gritty and passing 10 mesh.

5.1.2 Dry Milling

A sample of Tailings B was passed through the standard dry mill circuit shown in Figure 3-1. As in the first tailings most of the fibre was recovered on the 35 mesh screen. It had group 7 length and dust values, as seen in Table 5-2. The three lifts (Product #1, 2, 3) were mathematically blended into a single product and dust adjusted to an arbitrary dust level to compare with the fibre produced by the wet mill tests.

5.2 Wet Processing

The two-cone table flowsheet developed was still semi-continuous, requiring pumps for some material transfer, and, ultimately, batch processing on larger samples. Two main problems had to be solved in order to make the process continuous: an efficient method of material flow through the system had to be developed, and an efficient method of tailings removal. Tailings B samples were used to solve these problems.

5.2.1 Two-Cone Circuit: Gravity Feed

The most efficient method of materials transfer in the two-cone circuit was the gravity feed. The various components of the two-cone circuit were put on various levels, in order to eliminate all pumping in the system. This system could easily be applied to an upscaled situation.

Full sized plants regularly use multi-storied buildings; feeding the mill on the upper floor and disposing of products and waste on the lower floors.

5.2.2 Materials Transfer

The original two-cone design used a trommel screen between the two elutriating cones as a dewatering and dedusting device, while a thickener was used to dewater the material prior to feeding the concentrating table. It was determined that the second cone would work equally well without the prior dewatering stage. This freed the trommel, which replaced the thickener in front of the concentrating table. This new arrangement worked much more efficiently than the original.

The products from the concentrating table were collected in containers when no further processing was required. The table tailings and middlings could be collected and dewatered by decantation at this scale of process. The fibre concentrate produced by the table was pumped, using a small pump, over an 18" Sweco screen for further dewatering and dedusting. The Sweco screen was equipped with a rotary spray system and a 100 mesh screen, that effectively dewatered the material. During longer mill runs, it tended to get overloaded, suggesting that a 30" model would be required to provide the necessary capacity.

5.2.3 Tailings Removal

The elutriation cones, as designed, removed approximately 70% of the material as barren grit. In the original design, this reject was discharged as a cone underflow, and deposited in a sealed tank below the elutriation cone. This necessitated a batch process in the circuit. The wet system could remain continuous until these holding tanks below the cones were filled with reject material. Once the tanks were filled, the circuit would have to be shut down in order to empty them. The first cone rejected approximately 65% of the feed material, and therefore a more continuous method of tailings removal was required.

To improve the efficiency of tailings removal, a semi-batch process was designed, using a splitter on the cone underflow (see Figure 5-1). The splitter was attached to two tanks. Each tank could be isolated from

the circuit so that it could be emptied. The circuit could be running continuously, since only one tank was required at any one time. This system proved to be awkward and was not considered to be more than a laboratory design, but it allowed a continuous feed.

A second, more efficient continuous method of tailings removal was investigated and eventually incorporated into the circuit. Air lifts have been used to elevate solutions, slimes and, in certain cases, sand pulps in many types of operations. Advantages of an air lift over other transfer techniques is its simplicity of design and construction. The absence of moving parts reduces wear, expensive repairs and shutdowns.

Figure 5-3 shows the original design of the air lift built at Ontario Research. A two-inch diameter air lift was fabricated and connected to the first elutriation cone to continuously dispose of the reject generated in the cone underflow. A single 1/4 inch air line was attached to the bottom of the air lift to generate the bubbles required to move the material. The bubbles generated, however, were too large and too few to lift the material. A multi-tubed sparger replaced the air line, which provided sufficient lift.

The necessary dimensions of the air lift required a shallow slope in the pipe leading to the sparger. This often caused a build-up of material, resulting in plugging. A water purge was connected to flush the material down to the spargers, where it could be lifted and rejected.

The air lift was capable of carrying away the material rejected by the cone, but often was plugged by larger (1/2 - 1 inch) pieces of rock. The feed material to the cone was, therefore, screened on a 1/4" screen cloth in order to remove large (and always fibre barren by visual inspection) particles, eliminating this problem.

In order to maintain the efficiency of the elutriation cone, it was necessary to isolate its hydraulic regime from the air lift. The amount of water fed to the air lift would have to be able to balance the water discharge along with the reject. It was found that insufficient water was brought into the system by the water purge line, causing vortexing

and fluctuating water levels in the cone itself. In order to minimize this, a chamber was inserted between the cone and the air lift which would act as a buffer between the two flow regimes. Water was added to the buffer in order to balance the discharge, thereby isolating the cone.

Operating at minimum capacity (as close to "shut-off" as possible), the air lift proved to be oversized for the scale of the wet circuit. Its water consumption made it difficult to balance it with the rest of the system.

A second, downsized (1 inch diameter) air lift was constructed, and was designed with the same fittings and connections as the first. With the decreased volume, the system was able to handle the water discharge with a very slight increase in the bottom water spray of the cone. This system provided enough lift to remove all reject, and coupled with the buffer, it was sufficiently isolated from the cone to have little effect on the cone efficiency. The air lift discharged on a sieve bend in order to dewater the tailings. In this pilot plant operation, the discharged water was rejected. In a larger operation, it could be recovered and re-introduced into the circuit.

The air lift is a viable method of transferring material where an open bottomed discharge (on the cone) was not possible. It does, however, require greater amounts of water and air pressure. Where these are readily available, the air lift can be an economical method, though it does require some testing to efficiently lift the material. Other mechanical means, such as a belt system or an auger, may also be used in this type of operation.

Tailings B material was processed through this circuit, and it was found that a substantial amount of fibre was lost to the second cone, and the middlings on the concentrating table. It was concluded that the fibre needed to be continuously opened somewhere in the circuit. The original classification in the first cone produced a good fibre concentrate with little loss of fibre to the reject. Most of the coarse grit was removed during this stage. Processing the first elutriation cone overflow through a continuous attrition mill, prior to the second

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cone, opened the fibre, provided better classification, and resulted in substantially reduced middlings product. The final design of the continuous wet circuit is shown in Figure 5-3. A description of the attrition mill is given in Section 3.2.4.

5.2.4 Tailings B Wet Milling

Four separate samples of Tailings B material were processed through the standard two-cone flowsheet developed in this study. The first two, smaller samples were processed in the semi-batch process used to process Tailings A material. The second two samples were processed through the continuous circuit described in the previous sections. The mill and laboratory results are shown in Tables 5-3 and 5-4.

The mill data list the distribution of reject and product throughout the circuit. The head weight of each sample is indicated. A 3 mesh scalp was used only on the final sample, to ensure that the 1 inch air lift on elutriation cone #1 handled the size of the rejected material. This +3 mesh fraction was visually barren.

Tailing B fibre was quite dusty in both wet and dry products. The trommel screen was not as efficient in dedusting this material. Dust contents (-200 mesh) in the wet process were lower than in the dry, and strength measurements were higher.

TABLE 5-1
SCREEN ANALYSIS OF TAILINGS B

<u>Screen Fraction</u> <u>(mesh)</u>	<u>Total</u> <u>(Wt. %)</u>	<u>Fibre</u> <u>(Wt. %)</u>	<u>Wash Test</u> <u>(Wt. % -200)</u>
1/2"	2.2	-	-
4	8.0	-	-
10	22.2	trace	50.3
35	27.3	5.9	33.3
-35	40.3	-	-

TABLE 5-2

TAILINGS B, DRY MILL DATA

	<u>Wt. (kg)</u>	<u>Wt. %</u>
Reject #1	13.6	21.2
Reject #2	11.4	17.7
Reject #3	5.1	7.9
Reject #4	29.8	46.3
Product #1	.12	0.19
Product #2	.84	1.31
Product #3	.23	.36
Losses	<u>3.2</u>	<u>5.00</u>
Total	64.33	99.96

	Surface Area	<u>Bauer-McNett (Wt. %)</u>							
		Acc.							
<u>Sample</u>	<u>(cm²/q)</u>	<u>+4</u>	<u>+14</u>	<u>+14</u>	<u>+35</u>	<u>+200</u>	<u>-200</u>	<u>Rec.</u>	<u>FSU</u>
		<u>Dry Process</u>							
Product #1	4,200	30	18	48	5	8	40	0.2	-
Product #2	2,300	18	14	32	15	15	38	1.3	68
Product #3	8,800	2	5	7	12	22	59	3.6	35
Blend	-	7	8	15	13	20	52	5.1	-

<u>Mathematically Dust Adjusted</u>									
Product #1	-	40	24	64	7	10	20	0.2	-
Product #2	-	23	18	41	19	19	20	1.0	-
Product #3	-	4	10	14	23	43	20	1.8	-
Blend	-	12	13	25	22	33	20	3.0	-

TABLE 5-3

TAILINGS B WET MILLING, STANDARD WET CIRCUIT
(see Figure 5-1)

Sample	Head Wt. (kg)	+3M (Wt. %)	Elutriation Cone #1 (Wt%)		Elutriation Cone #2 (Wt%)		Concentrating Table (Wt%)			Trommel Unders Tailings(Wt. %)*
			Overflow*	Underflow	Overflow*	Underflow	Product	Middlings	Tailings	
Batch #1	39.5	-	45.5	54.6	38.8	6.6	2.8	5.5	9.5	21.0
Batch #2	45.4	-	46.4	53.2	40.1	6.3	1.5	1.5	11.7	25.8
Continuous 2"										
air lift	98.1	-	48.0	52.0	44.2	3.8	2.1	2.9	17.7	21.5
Continuous 1"										
air lift	192.0	26.1	22.2	51.7	18.1	3.1	3.1	4.9	6.1	5.0
Blend		13.4	34.3	52.3	30.0	4.0	2.6	4.0	10.2	13.6

TABLE 5-4

TAILINGS B WET MILLING, FIBRE QUALITY TESTING

	Surface Area	Bauer-McNett Wt. %							
<u>Sample</u>	<u>(cm²/g)</u>	<u>+4</u>	<u>+14</u>	<u>Acc. +14</u>	<u>+35</u>	<u>+200</u>	<u>-200</u>	<u>Rec.</u>	<u>FSU</u>
AC-1		16.3	12.4	28.7	10.7	19.2	41.4	2.8	-
AC-3		13.4	13.6	27.0	13.1	21.3	38.6	1.5	55
CF-2	4,700	5.7	7.2	12.9	12.8	45.9	28.3	2.1	60
CF-3	2,800	8.0	10.0	18.0	14.4	48.1	19.7	3.1	-
Composite Blend	-	10.7	10.7	21.4	12.7	34.8	31.1	2.3	-
<u>Mathematically Dust Adjusted</u>									
AC-1	-	22.3	16.9	39.2	14.6	26.2	20.0	2.1	
AC-3	-	17.5	17.7	35.2	17.1	27.8	20.0	1.2	
CF-2	-	6.4	8.0	14.4	14.3	51.2	20.0	1.9	
CF-3	-	8.0	10.0	14.3	14.4	47.9	20.0	3.1	
Composite Blend	-	12.6	12.4	25.0	14.8	40.3	20.0	2.0	

FIGURE 5-1
BATCH AND SEMI-BATCH TAILINGS REMOVAL

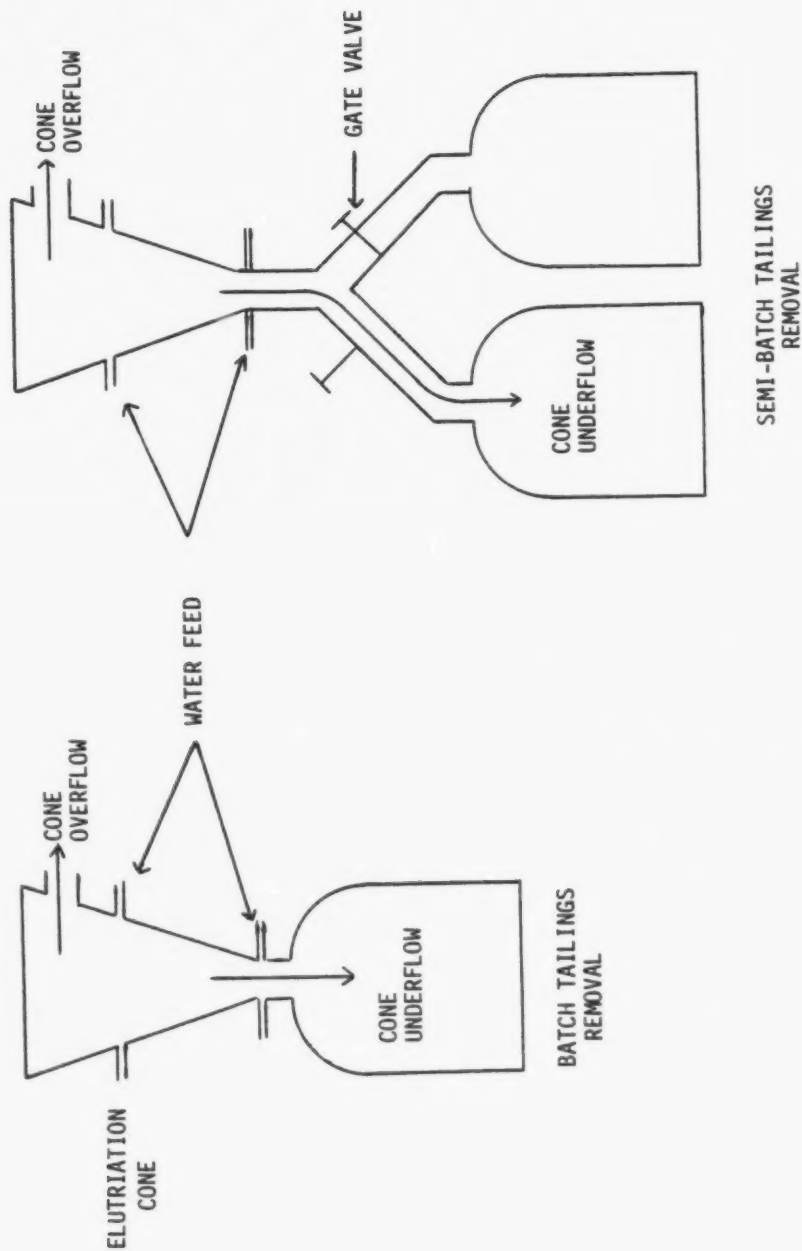


FIGURE 5-2
AIR LIFT TAILINGS REMOVAL

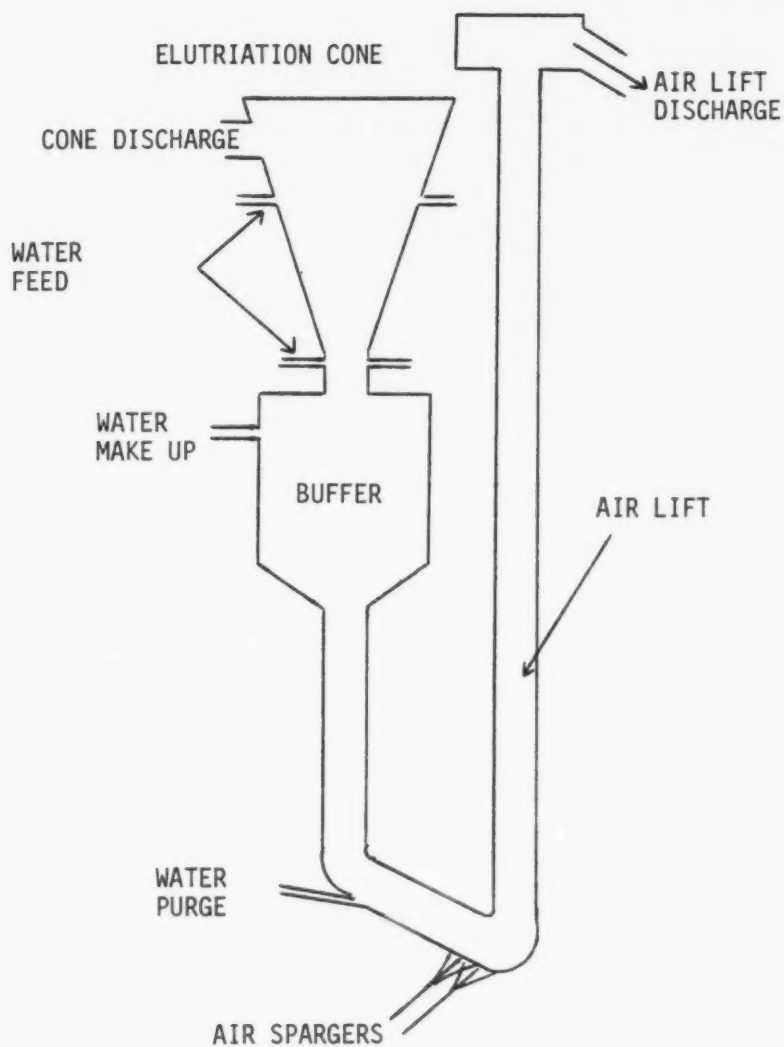
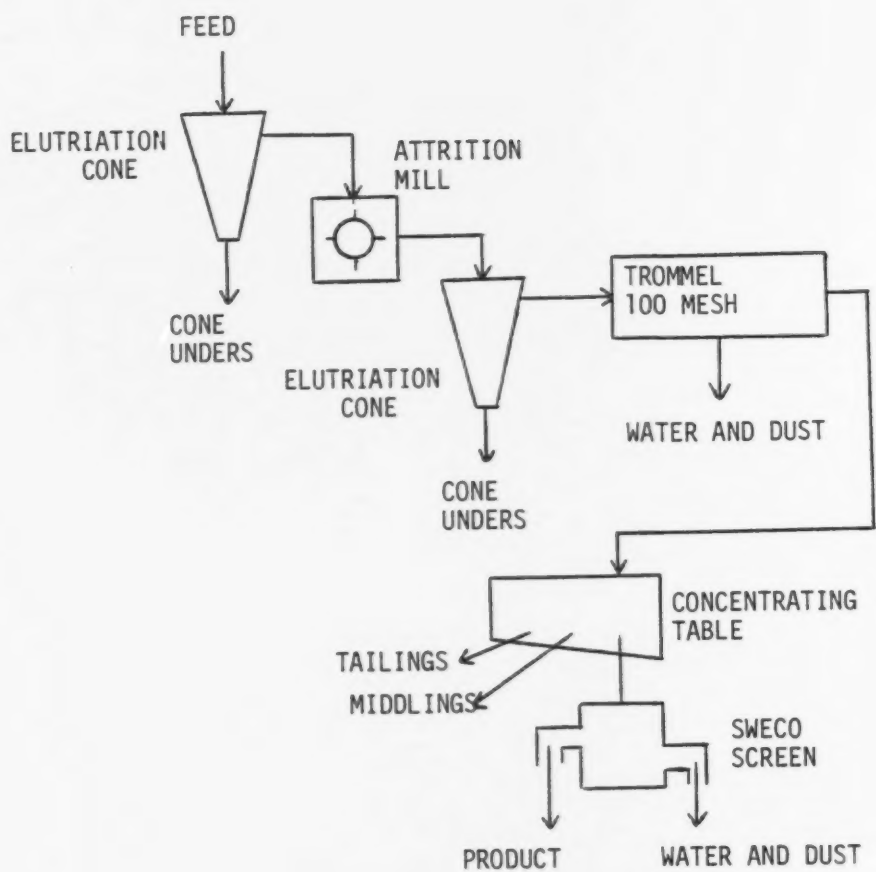


FIGURE 5-3

FINAL DESIGN OF TWO CONE CIRCUIT



6. TESTING RESULTS FOR TAILING C

The flowsheet development performed with Tailings A and B resulted in a two-cone elutriation system providing primary and secondary degritting stages. The overflow was fed to a dedusting and dewatering trommel, which in turn was fed to a concentrating table to produce a grit free fibre product. The final dewatering stage was accomplished with a Sweco 100 mesh screen. A continuous attrition mill between the first and second elutriation cone provided some fibre opening to enhance fibre recovery and reduce fibre losses to the middlings.

6.1 DRY PROCESSING

6.1.1 Screen Analysis

The rock and fibre size distribution of the tailings C material was determined. The results of this analysis are shown in Table 6-1. Approximately 90% of the material passed the 1/4 inch screen and 70% passed the 10 mesh. Fibre recovery was approximately 3.5%; most of it retained on the 35 mesh screen. A wash test conducted on this fibre indicated it to have a 30% dust content.

6.1.2 Dry Milling

Approximately 90 kg of tailings C were passed through the standard dry mill circuit for comparison to the wet milling techniques. Length and dust contents of the dry products suggest a group 6 or 7 recovery. The three products were mathematically blended into a single sample for comparison to the wet processed material. Results are listed in Table 6-2. The fibre recovered was very dusty, averaging approximately 60% -200 mesh. Strength values corresponded to a group 7 fibre.

6.2 WET MILLING

The continuous wet circuit developed and tested using the first two tailings samples was used to extract the fibre from this third and final sample. Three separate samples were passed through the fibre extraction circuit, ranging from 25 kg to approximately 180 kg. Mill and laboratory test data are listed in Table 6-3 and 6-4.

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Mass balances in the wet mill indicate a lower degree of grit rejection in the elutriation cones, suggesting that the material may be finer than the tailings samples previously tested. Fibre recovery averaged 3.3%, with significant length, measuring 21.1% greater than 14 mesh, and a dust content of approximately 19%. The fibre samples tested for strength gave low group 6 values.

TABLE 6-1
SCREEN ANALYSIS OF TAILINGS C

<u>Screen Fraction</u> <u>(mesh)</u>	<u>Total</u> <u>(Wt. %)</u>	<u>Fibre</u> <u>(Wt. %)</u>	<u>Wash Test</u> <u>(Wt. % -200)</u>
1/2"	2.0	-	-
4	8.8	-	-
10	30.7	0.1	44.3
35	26.8	3.4	30.2
-35	31.7		

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TABLE 6-2

TAILINGS C, DRY MILL DATA

	<u>Wt. (Kg)</u>	<u>Wt. %</u>
Reject #1	21.6	23.7
Reject #21	15.8	17.3
Reject #3	7.8	8.5
Reject #4	40.4	44.3
Product #1	.12	0.1
Product #2	1.0	1.1
Product #3	3.72	4.1
Losses	<u>0.81</u>	<u>0.9</u>
Total	91.25	100.0

	Surface Area	<u>Bauer-McNett (Wt. %)</u>							
		<u>Acc.</u>							
<u>Sample</u>	<u>(cm²/g)</u>	<u>+4</u>	<u>+14</u>	<u>+14</u>	<u>+35</u>	<u>+200</u>	<u>-200</u>	<u>Rec.</u>	<u>FSU</u>
		<u>Dry Process</u>							
Product #1	4,300	26	14	40	3	9	48	0.14	-
Product #2	2,400	20	16	36	16	11	37	1.1	65
Product #3	9,500	7	3	10	9	19	62	4.1	42
Blend	-	10	6	16	10	17	57	5.34	-

<u>Mathematically Dust Adjusted</u>									
Product #1	-	40	21	61	5	14	20	0.09	-
Product #2	-	25	20	45	20	14	20	0.86	-
Product #3	-	15	6	21	19	40	20	1.95	-
Blend	-	19	11	30	19	31	20	2.90	-

TABLE 6-3

TAILINGS C, WET MILLING DATA

Sample	Head Wt. (kg)	+3M (Wt. %)	Elutriation Cone #1 (WT%)		Elutriation Cone #2 (WT%)		Concentrating Table (WT%)			Trommel Unders (Wt. %)*
			Overflow*	Underflow	Overflow*	Underflow	Product	Middlings	Tailings	
#1	25.0	9.3	50.3	40.4	40.3	10.0	5.6	5.6	10.8	18.3
#2	50.4	9.9	20.6	69.5	18.8	1.8	1.7	0.4	7.2	9.5
#3	183.4	12.7	36.1	51.2	32.6	3.5	3.4	1.0	11.9	16.3
Blend	-	11.8	34.5	53.7	30.7	3.8	3.3	1.3	10.9	15.2

TABLE 6-4
TAILINGS C, WET MILL FIBRE QUALITY

	Surface Area	Bauer-McNett (Wt. %)							
		Acc.							
Sample	(cm ² /g)	+4	+14	+14	+35	+200	-200	Rec.	FSU
#1	1,600	12.9	12.0	24.9	11.4	43.4	20.3	5.6	-
#2	4,400	5.0	7.5	12.5	14.5	59.8	13.3	1.7	75.9
#3	2,300	9.3	9.9	19.3	11.6	50.5	18.7	3.4	66.9
Blend	-	10.5	10.6	21.1	12.0	48.3	18.5	3.6	-

Mathematically Dust Adjusted									
#1	-	12.9	12.0	24.9	11.4	43.6	20.0	5.6	
#2	-	4.6	6.9	11.5	13.4	55.2	20.0	1.8	-
#3	-	9.2	9.7	18.0	11.4	49.7	20.0	3.5	-
Blend	-	10.3	10.4	20.7	11.7	47.5	20.0	3.7	-

7. WET AND DRY MILL COMPARISON

The comparison between wet and dry techniques can be done by an examination of the quantity and quality of fibre produced, and of the energy required to produce that fibre. Flowsheet development work done with Tailings A material resulted in the two-cone (elutriation cone), trommel and table circuit that was compared to the standard dry flowsheet used in this study.

Much of the work done on Tailings A was flowsheet development and therefore cannot be used in a comparative study between wet and dry processes. The final flowsheet developed closely resembled that used in the other two tailings samples. The two-cone flowsheet developed using Tailings A was modified to increase efficiency and speed, but used the same separation and dedusting equipment throughout. Comparison between the wet and dry processes was made using the standard dry circuit and the two-cone circuit used in the Tailings B and C portions of this study. The Tailings A two cone circuit can be compared to the modified version used on later samples.

The modifications of the original two-cone circuit affected the practicality of the circuit, and not its efficiency, or its product. The attrition mill, put into the circuit to help open the fibre between elutriation cones, resulted in a smaller, and much more barren, middlings product on the concentrating table. This eliminated the need to reprocess the middlings and resulted in a single fibre product, or concentrate on the table. The two products collected in Tailings A were, in all cases, very similar in length and dust content. This would suggest that they could have been collected as a single sample. For these reasons, a direct comparison can be made between the original and modified two cone circuit.

Other modifications such as the gravity feed and the airlift affected the materials handling aspects of the circuit only, and not the quality or effectiveness of the process.

7.1 Energy Comparison

The energy comparison was done for the circuits themselves, irregardless of the sample processed. The equipment used in both the wet and dry process was considered to be overpowered and would therefore use as much power (running empty) as running with material passing through or over it. Processing times for individual samples were noted, and it was found that processing time through a circuit did not vary with different tailings material. An energy consumption could therefore be calculated by determining the power draw of a particular piece of equipment, and the amount of time that particular piece of equipment was in use. A standard amount of sample was processed for each circuit. The results are listed in Table 7-1.

The wet circuit could require 30% less energy than the dry circuit. The energy calculation however, does not take into account the energy required for environmental control and aspiration in the dry process. This is a major energy expenditure not perceived to be required in the wet process. The energy audit also excludes the energy required to fully dry the asbestos fibre. Mechanical dewatering can bring the moisture content down to approximately 20%. Below this moisture content heat is required. In the energy study, it was assumed that 20% moisture would be acceptable to the market.

Materials transfer in both systems was considered to be gravity feed. An exception was a single pumping stage in the wet circuit.

7.2 Wet Circuit Capacity

A comparison between the wet and dry circuit capacities used in this study would not be a significant measurement because neither process is utilized on a commercial scale. The capacity and throughput of the wet circuit was determined and quantified so that upscaling estimates can be made to compare with existing commercial dry circuits.

Figure 7-1 shows the capacity and throughput of the present wet circuit. Water consumption is shown in litres per minute. The throughputs are indicated as slurries of given concentration. The by-products of this circuit (i.e. cone underflows and table products) are indicated by estimated weight percent.

Water consumption used in the airlift was not included in the total water consumption. It was not part of the fibre extraction process and could be replaced by several other systems not requiring water.

7.3 Wet and Dry Fibre Recovery and Quality Comparison

The fibre quantity and quality produced by the wet and dry methods were compared using the following tests in accordance with the QAMA Asbestos Test Manual:

- o Turner and Newall Rapid Surface Area
- o Bauer-McNett Wet Classification
- o Fibre Strength Unit.

Since the two processes generated different fibre products, a direct fibre to fibre comparison was not feasible. A composite blend of fibre from each process was therefore mathematically calculated and dust adjusted to a common dust level. Using this procedure, a Bauer-McNett length classification and a recovery can be used to compare the two processes. Table 7-2 and 7-3 list the comparison for the three tailings samples.

Table 7-2 compares the recovery and quality of the fibre recovered from both the wet and dry circuits. The quality and recovery values given represent a blend of fibre from each circuit.

The quality of fibre concentrated by the dry process was consistently lower than that generated by the wet process. The differences in dust contents was also reflected in the recoveries. Having significantly high dust levels the dry process also gave significantly higher recoveries.

In order to make a marketable grade of fibre, dust adjustment would be required. The dry processed fibre would have to undergo extensive dedusting to produce a fibre with any strength. The wet processed fibre has significantly lower dust levels and would not require as much dust removal. Dust removed in the wet process would involve additional washing in the trommel screen. Dust removal in the dry process would involve several passes through a dry dust extractor circuit. The wet

dedusting system is most likely more efficient than the dry system, from a fibre quality point of view. A program of study would have to confirm this.

The quality of the fibre from the two processes can be directly compared by dust adjusting the blends to a common dust level, as shown in Table 7-3. Tailings A material had a higher recovery with the wet process than with the dry process. Fibre quality was the same, according to the Bauer-McNett data. Tailings B had greater recovery by dry methods with equal fibre quality. Tailings C had greater recovery, but inferior fibre quality with the wet process.

7.4 Wet and Dry Process Comparison

Comparison of wet and dry processed fibre quality and recovery appeared to be somewhat inconclusive. When standardized to a common dust level, the two fibre concentrates showed no distinct difference. This indicates that the wet fibre extraction process is as efficient as the dry. In order to compare the relative merits of one method over the other, comparisons must be made on the quality of raw fibre concentrate that they produce, and the overall energy they require to produce these concentrates.

The wet circuit produced a consistently cleaner raw fibre concentrate as shown in Table 7-2. In order to make a product of equal dust content, a greater amount of dust removal would have to be done to the dry fibre concentrate than to the wet fibre concentrate. Although not specifically tested in this study, dust removal by dry methods is more difficult (i.e. requires more energy) than by wet methods.

TABLE 7-1

ENERGY SURVEY

<u>Equipment</u>	<u>Estimated Contribution of Energy</u>
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Wet Process: 50 kg feed

Concentrating Table	330 WH
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Pumps + Mixers	80 WH
----------------	-------

Feeders	30 WH
---------	-------

Trommel	150 WH
---------	--------

Total energy = 590 WH
= 236 WH/kg Fibre Product

Dry Process: 50 kg

Rotex Screener	440 WH
----------------	--------

Hazemag Hammer Mill	100 WH
---------------------	--------

Stedman Fibrizer	670 WH
------------------	--------

Total energy = 1210 WH *
= 346 WH/kg Fibre Product

* Aspiration and environmental control energy not included
(see Section 7.1)

TABLE 7-2

MATHEMATICALLY BLENDED PRODUCTS
FOR FIBRE QUALITY COMPARISON

Sample	Process	Bauer-McNett						Rec
		+4	+14	Acc +14	+35	+200	-200	
Tailings A	Dry	3	5	8	10	23	59	9.0
	Wet	8	12	20	18	54	8	5.4
Tailings B	Dry	7	8	15	13	20	52	5.1
	Wet	11	11	22	13	35	30	2.3
Tailings C	Dry	10	6	16	10	17	57	5.3
	Wet	11	11	22	12	48	18	3.6

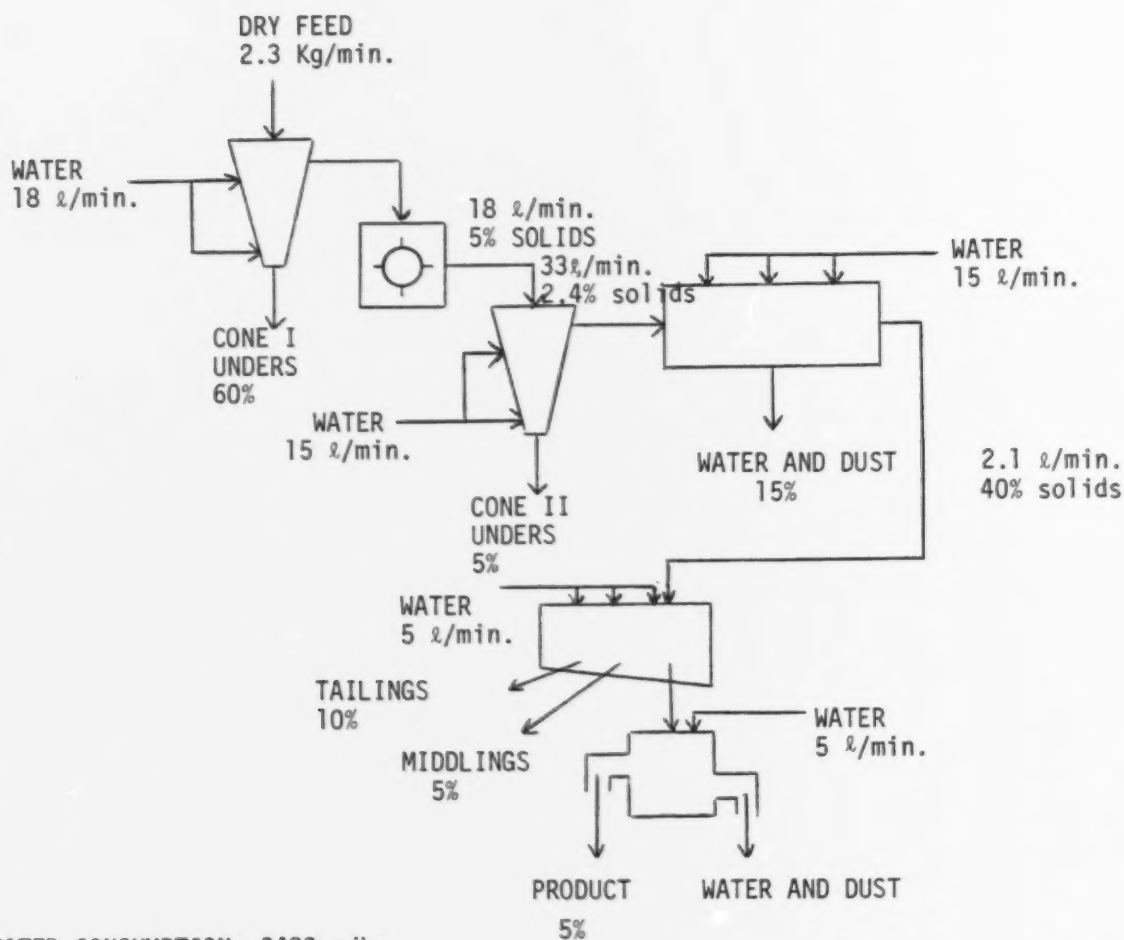
TABLE 7-3

MATHEMATICALLY DUST ADJUSTED BLENDS
FOR FIBRE QUALITY COMPARISON

Sample	Process	Bauer-McNett							
		+4	+14	Acc	+14	+35	+200	-200	Rec
Tailings A	Dry	6	10	16		20	44	20	4.5
	Wet	7	10	17		16	47	20	6.2
Tailings B	Dry	12	13	25		22	33	20	3.0
	Wet	13	12	25		15	40	20	2.0
Tailings C	Dry	19	11	30		19	31	20	2.9
	Wet	10	10	20		12	48	18	3.7

FIGURE 7-1

WET CIRCUIT CAPACITY



WATER CONSUMPTION: 3480 l/hr.

ORE CAPACITY : 138 Kg/hr.

8. CONCLUSIONS

This study was conducted in order to accomplish two main tasks. The first task was a study of surfactants, and their effect on asbestos fibre on a dry milled Chrysotile fibre selected by the scientific authority. It was found that, although chemical treatment of asbestos does show some indication of a gentle opening of fibre bundles, problems associated with surfactant removal supersedes any possible benefits.

The second task was to develop a viable wet extraction circuit capable of processing asbestos tailings material. Tailings material was chosen for this study because the size reduction, and therefore energy, required to liberate the fibre that had already been put into the material during dry processing of the asbestos ore. This eliminated the need for crushing or grinding equipment. Studies concentrated on fibre recovery through classification, and crudy fibre opening with operations such as the attrition mill.

Fibre concentrate produced by the wet extraction circuit developed in this study was then compared to fibre concentrates produced by a standard dry core mill circuit. Several conclusions may be reached. The final form of the wet extraction circuit developed has two elutriation cones providing primary and secondary rock and grit removal. A high speed attrition mill placed in between the two cones provided some opening to the crudy fibre that overflowed the first elutriation cone. The second cone overflow was passed through the rotating trommel screen where it was dewatered and washed by inner and outer sprays. The partially dewatered and dedusted material fed onto the concentrating table, where it was classified, giving a fibre concentrate, a middlings product and a tailings. Fibre products were dewatered and further dedusted on a Sweco screen equipped with a rotary spray. The use of the attrition mill between the elutriation cones opened the crudy fibre sufficiently that the middlings product on the table was minimized. The material rejected by the cones was visually barren. The size distribution of the tailings indicated that little unliberated fibre of significant length could be recovered (See Figure 5-3).

The trommel screen developed at Ontario Research Foundation was found to be a quite efficient dewatering and dedusting device. The inner 100 mesh screen was used to effectively dewater the material. Much of the dewatering took place in the first 30 cm of the trommel. The inner and outer sprays continually washed the screen to prevent binding, and washed the dust out of the fibre. Where required, additional passes provided further dedusting.

The high speed attrition mill was used to open the crudy fibre that overflowed the first elutriation cone. It was found that this was the only opening or fibrizing needed to collect the fibre. Some fibre was still lost to the rejects, but was not considered to be significant in quantity to warrant further recovery.

The energy survey conducted on the wet and dry processes indicated that the wet process required less energy to produce a given amount of fibre than did the dry process. This study indicated an energy savings of approximately 30%. This study did not include the cost of water supply for the wet process, or the energy cost for the aspiration and environmental control needed for the dry circuit. It is recommended that an energy comparison be made with commercial dry circuits. This would give a much more significant measure of the relative practicality of the wet process.

The quality of the fibre products from the individual test runs of each tailings sample were tested, using the Bauer-McNett Classifier, the Turner and Newall Rapid Surface Area, and the Fibre Strength Unit. The fibre recovered using the wet extraction circuit was consistently less dusty (i.e. less -200 mesh) than that produced by the dry circuit. The wet circuit also produced fibre with a higher strength.

When mathematically blended and dust adjusted to an arbitrary dust level, fibre recovered from the wet circuit showed no consistent difference than fibre recovered from the dry circuit, for a given tailings sample. This suggests that the wet extraction circuit is, at least, as efficient in recovering fibre as the dry.

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Work and development conducted on the airlift was considered to be somewhat separate from the actual developments of the wet circuit. The airlift was intended to handle material that would not affect the performance of the circuit, or the products that the circuit generated. The test work did, however, indicate a possible means of material transfer in a plant situation.

The wet extraction circuit is a viable means of extracting liberated fibre from rock. Energy and raw fibre quality indicated advantages of the wet circuit over the dry. Direct fibre quality comparisons using standard dust levels indicate the wet circuit to be as efficient as the dry circuit.


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APPENDIX

SAMPLE CALCULATIONS

BAUER-McNETT BLENDING SAMPLE CALCULATIONS

Product	Bauer-McNett (Wt. %)						Rec.
	+4	+14	Acc. +14	+35	+200	-200	
Product #1	6	10	16	19	56	9	3.9
Product #2	12	16	28	16	50	6	1.5
Blend	8	12	20	18	54	8	5.4

The table above is reproduced from the net mill data for Tailings A (Table 4-9). The three products will be mathematically combined.

- a. The total recovery = 5.4%.
- b. The distribution of the two products:
 Product #1: $3.9/5.4 = .722$
 Product #2: $1.5/5.4 = .278$
- c. The Bauer-McNett +4 mesh fraction is calculated.
 Product #1 $6 \times .722 = 4.3$
 Product #2 $12 \times .278 = 3.3$
 Blend 7.6 , rounded off to 8.

2. DUST ADJUSTMENT CALCULATIONS

The blend from Tailings A calculated in the previous section will be used in the sample calculations. The dust content (-200 mesh fraction) will be adjusted to 20%.

- a. The adjusted +4 mesh Bauer-McNett value is calculated by:

$$+4 \text{ (ADJ)} = +4 \times \frac{(100 - \text{standard dust level})}{(100 - \text{original dust level})}$$

$$+4 \text{ (ADJ)} = 8 \times \frac{(100 - 20)}{(100 - 8)}$$

$$= 6.9, \text{ rounded off to } 7$$

b. Dust adjusted recovery is calculated by

$$\text{REC (ADJ)} = \text{REC} \times \frac{(100 - \text{Original Dust Level})}{(100 - \text{Standard Dust Level})}$$

$$= 5.4 \times \frac{(100 - 8)}{(100 - 20)}$$

$$= 6.2$$